The Association
of
Engineering and Shipbuilding Draughtsmen.

Fire and Fire Protection with Particular Reference to Ships.

By R. G. FURNIVALL
(on the Staff of the Director of Naval Construction,
Admiralty, Bath).

Published by The Association of Engineering and Shipbuilding Draughtsmen,
Onslow Hall, Little Green, Richmond, Surrey.

SESSION 1952-53.

Price 3/-

Printed by Milne, Tannahill & Methven, Ltd. (T.U.), 12-14 Mill Street, Perth.

ADVICE TO INTENDING AUTHORS OF A.E.S.D. PRINTED PAMPHLETS.

Pamphlets submitted to the National Technical Sub-Committee for consideration with a view to publication in this series should not exceed 9,000 to 10,000 words and about 20 illustrations, making a pamphlet of about 40 to 48 pages. The aim should be the presentation of the subject clearly and concisely, avoiding digressions and redundance. Manuscripts are to be written in the third person.

Drawings for illustrations should be done either on a good plain white paper or tracing cloth, deep black Indian ink being used. For ordinary purposes they should be made about one-and-a-half times the intended finished size, and it should be arranged that wherever possible these shall not be greater than a single full page of the pamphlet, as folded pages are objectionable, although, upon occasion, unavoidable. Where drawings are made larger, involving a greater reduction, the lines should be made slightly heavier and the printing rather larger than normal, as the greater reduction tends to make the lines appear faint and the printing excessively small in the reproduction. In the case of charts or curves set out on squared paper, either all the squares should be inked in, or the chart or curve should be retraced and the requisite squares inked in. Figures should be as self-evident as possible. Data should be presented in graphical form. Extensive tabular matter, if unavoidable, should be made into appendices.

Authors of pamphlets are requested to adhere to the standard symbols of the British Standards Institution, where lists of such standard symbols have been issued, as in the case of the electrical and other industries, and also to the *British Standard Engineering Symbols and Abbreviations*, No. 560, published by the B.S.I. in 1934 at 5/-. Attention might also be given to mathematical notation, where alternative methods exist, to ensure the minimum trouble in setting up by the printer.

The value of the pamphlet will be enhanced by stating where further information on the subject can be obtained. This should be given in the form of footnotes or a bibliography, including the name and initials of the author, title, publisher, and year of publication. When periodicals are referred to, volume and page also should be given. References should be checked carefully.

Manuscripts, in the first instance, should be submitted to the Editor, *The Draughtsman*, Onslow Hall, Little Green, Richmond, Surrey.

For Pamphlets, a grant of £20 will be made to the Author, but special consideration will be given in the case of much larger pamphlets which may involve more than the usual amount of preparation.

The Association of Engineering and Shipbuilding Draughtsmen.

Fire and Fire Protection with Particular Reference to Ships.

By R. G. FURNIVALL

(on the staff of the Director of Naval Construction, Admiralty, Bath).

"A little fire is quickly trodden out, which,
being suffered, rivers cannot quench."
—*King Henry VI. Act* 4.

Published by The Association of Engineering and Shipbuilding Draughtsmen,
Onslow Hall, The Green, Richmond, Surrey.

SESSION 1952-53.

6/53

CONTENTS.

FIRE AND FIRE PROTECTION WITH PARTICULAR REFERENCE TO SHIPS.

By R. G. Furnivall.

1. THE INCIDENCE OF FIRES.

Introduction.

The purpose of this booklet is to explain briefly the phenomenon of fire and to present a picture of the more general methods of combating it and the equipment used, particularly in ships. The survey is by no means exhaustive but its scope is as wide as can reasonably be expected in a work of this size.

Causes of Fires.

In ships in port, welding and burning operations, smoking materials and matches, stoves and flues, and electrical short circuits, are mainly responsible. Causes of fires at sea, when it has been possible to determine them, include short circuits, dangerous commodities, spontaneous combustion, oil leaks, etc. Generally, ship fires are most commonly initiated in oily waste, sacking, rope, insulation and furnishings.

Records of fires in H.M. Ships over a 3-year period show that 23% were caused by ignition of oil fuel ; 23% by the ignition of petrol or paraffin ; 20% were of electrical origin ; 11% arose out of the ignition of carbonaceous material by sparks from welding and burning operations ; 20% could be ascribed to faulty or inadequate heat insulation, spontaneous combustion, smoking, etc. ; and a small percentage was cinematograph film fires. None of these fires, totalling 280 reported instances, arose out of enemy action. Of those naval vessels damaged by enemy action during the last war, 15% had fires of which half were serious.

Fires in Tankers.

Tankers are usually very clean vessels. Their working is governed by stringent regulations which, with the vigilance exercised by personnel, makes instances of fires comparatively rare. When they do occur, however, the terrific heat radiation makes them difficult to deal with. These vessels are in their most dangerous condition during loading or discharging. When the tanks are full there is little risk, but as the air space increases the

danger of an explosion rises considerably. Tankers have steam and water lines, and also exhausters, for making tanks gas free. Requirements for firefighting equipment are laid down in regulations which are discussed later.

Fire Protection.

The first objective in all fire protection is to prevent loss of life or personal injury, and legislation therefore emphasizes the requirement for means of escape. Additionally and more positively, fire protection aims at the elimination of fire causes, the provision of fire-resistant barriers, and the detection and extinguishment of fires, and it is these factors which are discussed in succeeding pages. Before doing so, however, it is necessary for a better understanding of the problem to consider very briefly the fundamental principles of combustion.

---

2. BRIEF NOTES ON CHEMISTRY OF FIRE.

Fire may be defined as rapid oxidation with the evolution of light and heat. Oxidation is a chemical reaction which takes place between a substance and oxygen, normally from the air. It is always accompanied by the generation of heat which, in many instances, as in the oxidisation of iron to form iron oxide or rust, is dissipated immediately with no apparent rise in temperature of the substance.

Before combustion can occur, three factors must be present together. They are fuel, oxygen, and a source of heat. Extinction can be effected by the elimination of any one of these. Removing the fuel is called STARVING ; excluding oxygen is SMOTHERING ; and reducing the temperature is COOLING.

In the burning of most substances, including solids, the actual combustion takes place only after the substance has been vaporised by heat, the visible flame emanating from the burning vapour. Evolved vapours of vaporisable substances, especially inflammable liquids, will, *in the presence of a flame*, "flash" at a certain temperature of the combustible, called the "flash point." The flash will die away when the source of ignition is removed unless the surrounding layers of combustible have been raised to the slightly higher "firepoint."

The ignition temperature of a substance is that temperature at which ignition will take place, without the direct application of flame, if it is uniformly heated in the presence of air.

Spontaneous combustion occurs as the result of heat generated by the reacting substances themselves, with no external application of heat. In some instances the necessary heat may be generated

by bio-chemical means, such as occasionally occurs in haystacks and other vegetable matter.

Most animal and vegetable oils possess the property of absorbing oxygen, the process of oxidation resulting in an increase in temperature, often sufficient to involve spontaneous ignition. The drying oils are particularly hazardous, and it is their faculty of oxygen absorption that makes them so dangerous when soaked up by fabrics. Linseed oil in association with cotton or jute is most hazardous. Tung oil, codliver oil and seal oil are also dangerous in this respect. The presence of as little as 5% of fat or oil may cause fibrous materials to ignite spontaneously. Fibres uncontaminated with oil may also ignite themselves if they contain impurities.

There have been many instances of spontaneous combustion of coal. Self-ignition seems to occur most readily in soft coals and in those which contain a high percentage of iron pyrites. Other factors are freshness of the exposed fuel ; height of the pile ; size of the coals ; and the state of ventilation. As to the last factor, this should be on the basis either of supplying so much air that heat is dissipated, or restricting air supply so that oxidation is smothered. The second method is usually the more practicable.

Self heating may occur in certain types of cargo, particularly in cereals and oil bearing seeds. As regards esparto grass, jute, flax, baled cotton, etc., spontaneous combustion may also occur, but it is by no means certain that it arises from the material itself. It may well be that the heating process is initiated by oily or contaminated material picked up during baling or in transit.

Inflammable Liquids and Gases.

Inflammable liquids include fuel oils, lubricating oils, gas oil, diesel oil, petrol, paraffin, lamp oil, alcohols, ethers, etc. Gases include hydrogen, carbon monoxide, methane, and acetylene. It should be noted that oxygen, which supports the combustion of all ordinary combustibles, is itself non-combustible.

The fire hazard of an inflammable liquid may be gauged by its flash point, which is the temperature at which it will give off sufficient vapour to flash *if flame is applied in the presence of air.* At the flash point temperature an inflammable liquid becomes dangerous. A petroleum spirit is defined in the Petroleum Act as any mineral oil having a flash point below 73°F. The commonest of these are petrol and benzol. The flash point of most petrols is well below the freezing point of water, which means that they are potentially dangerous, even in the winter.

An inflammable gas, or the vapour of an inflammable liquid, is only ignitable when mixed with air in certain proportions by volume. These mixtures are called inflammable or explosive mixtures, and are said to be within the "inflammable" or "explosive

limits." For each gas or vapour there is an upper and a lower limit. Below the lower limit there is insufficient vapour, and the mixture is said to be too lean. Above the upper limit there is too much vapour and not enough air. The mixture is too rich. This will have a familiar sound to motorists. The perfect mixture will produce an explosion. Near the limits, ignition would be in the nature of a puff of flame. Outside the limits there would be no ignition at all. In the case of petrol, the lower limit is 1·4% by volume in air, the upper limit being 6·4% by volume. A concentration of 2·6% by volume would form a mixture having the maximum explosive effect.

Petrol is the most common and best known inflammable liquid in general use to-day, and yet its dangers are often quite unrealized. The disaster at a Bristol garage in 1951 is a case in point. It needs only a very small quantity to produce a serious explosion. In a receptacle, it is sufficient for the sides to be wet. One gallon of petrol gives about 25 cubic feet of pure vapour and this, diffused into the air, could produce nearly 2,000 cubic feet of inflammable mixture. A cupful of petrol has the potential explosive power of 5 lbs. of dynamite.

The table below gives flash points, ignition temperatures in air, and limits of inflammability of some of the better known gases and vapours :—

Substance.	*Flash Point °F.*	*Ignition temperature °F.*	*Limits of inflammability. Percentage by volume with air.*	
			Lower.	*Upper.*
Petrol	Minus 45 to 0	495	1·4	6·4
Kerosene ...	85-105	500	1·2	6·0
Diesel Oil ...	168	520	similar to petrol once the oil is sufficiently heated.	
Heavy Fuel Oil	230	500		
Lubricating Oil	500	700-800		
Acetone ...	Minus 4	440	2·5	9·0
Hydrogen ...	—	550	4·0	75·0
Carbon Monoxide	—	570	12·5	74·0
Methane ...	—	650	5·0	15·0
Acetylene ...	—	335	2·4	80·0
Coal Gas ...	—	650	5·3	31·0

3. EXPLOSIONS—DUST HAZARDS—STATIC ELECTRICITY.

Explosions.

An explosion may be defined as an extremely rapid chemical reaction with the evolution of great heat and a large gaseous volume. The sudden release of energy, so fast as to be practically instantaneous, and the tremendous velocity of the wave of detonation, produces the shattering effect.

There is no sharp demarcation between a fire and an explosion. Very often the latter term is applied to what is in fact a rapidly spreading fire, for which a more appropriate phrase might be "flash-fire."

The force of an explosion depends more upon the rate of release of energy than upon its quantity, and even in an unconfined space, pressure develops in the immediate vicinity owing to the resistance of the air. In a picric acid explosion the speed of the wave of detonation may be as high as 26,000 feet per second. For dynamite the wave velocity is stated to be 20,000 feet per second.

So far as inflammable liquids are concerned, explosions inside tanks which contain them are infrequent. The risk is much greater in an empty tank, or when air enters through vents as the liquid is drawn off. An explosion of a petrol vapour-air mixture may generate a gauge pressure of about 105 p.s.i. in a matter of milliseconds.

Dust Hazards.

The hazard occasioned by combustible dust clouds is mainly due to the greatly increased surface area exposed to the air for oxidation. Dust is a solid in such a finely divided state that its particles, if disturbed, will remain suspended in air for an appreciable period. They tend to fall slowly because the friction of the air balances the acceleration due to gravity, leaving the particle to drop at a very small, steady velocity.

There is a wide range of hazardous dusts, including those derived from all organic materials (*i.e.*, carbon compounds), particularly seeds, tea, grains, wood, sugar, starch, soya beans, resin, gums, coal, etc. The products of the processes of vegetable life are always hazardous in dust form, and their synthetic equivalents are almost equally so. Amongst inorganic dusts, sulphur has the worst record, whilst metallic dusts such as those from aluminium or magnesium are dangerous. Iron dust is liable to explode. Coal dust presents a hazard, that from bituminous coals having a higher degree of risk than dust from anthracite. Dusts containing a large proportion of silicates are relatively safe. In fact, in some coal mines the roads are coated with fine stone dust to reduce the fire risk when coal dust is disturbed by draughts.

Incidents involving dusts are rare in ships, but of course the possibility exists wherever combustible dusts are concerned. In 1943 there was an explosion when pitch was being loaded into a vessel where illumination was provided by naked lights. M.O.T. Circular 1816/1947, defining conditions of stowage of dangerous goods in ships, refers to powdered charcoal, activated carbon, lamp black or carbon black, and sulphur powder, as presenting dust explosion hazards.

A cloud of combustible dust will behave in many respects, from a fire risk point of view, just as if it was a gas or vapour. Before ignition can take place there must be present together, oxygen and a sufficient source of heat. The dust-air concentration must be between certain limits, which are wider than those for the corresponding vapour-air mixture. It has been stated that amongst the more dangerous dusts, a density of 0·02 to 0·03 ounces per cubic foot in air represents the lower limit. A concentration of 0·02 ozs. per cubic foot represents a dense cloud in which breathing would be difficult. The upper limits have not been determined. It should be borne in mind that a layer of dangerous dust $\frac{1}{16}$ inch thick over 1 square foot will provide 100 cubic feet of explosive mixture in air.

Dust clouds require a greater amount of heat for ignition than a vapour. When ignition takes place, the rate of spread is generally very rapid. Clouds of dust may be ignited by a wide variety of causes including flames, hot gases, hot bearings, sparks from mechanical or electrical sources, and static electricity. They may even be ignited spontaneously. Coal and rubber dusts possess this property. Dusts which are contaminated with the drying oils are also liable to ignite in this way.

Since such clouds are a normal adjunct to many manufacturing processes, it is a matter of primary importance to reduce the risks to a minimum. Preventive measures include prohibition of naked lights, careful attention to lubrication, check of wiring, removal of metallic foreign matter by suitable separators, earthing of machinery, enclosure of grinding machinery in blast proof spaces, and the use of dust extracting devices. Good housekeeping, especially the systematic prevention of dust accumulations, is probably the most important precaution.

Whenever inflammable dusts are the natural outcome of manufacturing processes, venting should be provided to minimise explosive effects. This can be done by means of hinged flaps or doors which open under pressure. It is understood that the Safety in Mines Research Department favours venting by means of a light door of sheet steel in steel framing, fitted in steel grooves lined with greased felt. An area of $1\frac{1}{2}$ to 3 square feet per 100 cubic feet of room capacity is normally provided, but as a result of modern research into rate of pressure rise, 1 square foot per 20

cubic feet is now recommended for carbonaceous dusts and twice that amount for metallic dusts. It should be noted that the average structural walls cannot withstand more than about 2 p.s.i. gauge pressure, whereas generated pressures may be anything from 50 to 150 p.s.i.

It is a difficult matter to distinguish between a dust fire and a dust explosion. Generally what happens is that the flash or explosion ignites surface dust and this propagates the fire. The main risk arising out of dust explosions may therefore be the rapid firing of settled dust accretions on combustibles such as wood or textiles.

Dust fires cannot be controlled in the same way as ordinary fires, and prevention, as always, is the best safeguard. Except with metal dusts rapid suppression may be effected by an automatic sprinkler installation, and although there are cases on record of failure, due to damage caused by the initial explosion, this still provides possibly the most satisfactory protection.

The Factory Division of the Ministry of Labour and National Service is associated with investigations into the reduction of damage through dust explosions, and is accessible for advice on the problem generally.

Static Electricity.

This is a natural phenomenon. It is generated by friction or by bringing together and then separating two substances, or by other means. Lightning is the best-known example. It is impossible to prevent static, but the danger of sparking can be avoided by conducting it to earth before an accumulation is built up. The hazards are greatest wherever there are combustible gases, vapours, or dusts. Sparks from static charges are not normally of sufficient duration, nor have they enough heat, to ignite solids.

If fur or silk is rapidly brushed, charges of static electricity accumulate, and will spark unless earthed. For this reason it is dangerous to use petrol or other inflammable liquid for cleaning clothing. Many fires have occurred in dry cleaning plants through generation of static.

When petrol, which is a non-conductor, is discharged through a nozzle, the nozzle becomes charged, and unless suitable earthing arrangements are made, a spark will ultimately occur with possibly disastrous results. Road tankers are always provided with a conductor to earth, sometimes in the form of a trailing chain. Special arrangements are made to provide adequate bonding when fuelling aircraft, or embarking petrol in an aircraft carrier, or elsewhere.

Fires in operating theatres have been traced to the sparking of charges built up by the movement or rubber-tyred trolleys,

when ether has been present. To overcome this, the wheels may be fitted with conducting rubber. If this is not done, a trailing chain is always employed.

The passage of belts over pulleys in industrial premises produces static electricity which may attain very high potentials, over 29,000 volts having been recorded. Where there is a fire hazard due to the presence of inflammable dust or vapour, the charge must be collected from the belt by means of grounded collecting combs or copper brushes. If the machinery is earthed, conducting rubber belts may be used.

Under some circumstances, the issue of an inflammable gas from a cylinder, in which it has been compressed, may result in the generation of a static charge. To avoid this, care should be taken to ensure that the delivery orifice is free from rust, the presence of which would increase turbulence and add considerably to the frictional effect ; and the cylinder itself should be earthed.

A warm dry atmosphere is conducive to static, so that a degree of humidification provides an additional safeguard. A very slight film of moisture has sufficient conductivity to drain off charges as they are formed.

Of the two most probable causes of the Avonmouth Docks fire in September, 1951, one was said to be the ignition of inflammable vapour by a static spark. It was stated that it would be possible for a dip tape to take up a charge of static electricity from the oil in the tank, and to discharge by sparking against the edge of the manhole through which the dip tape was inserted.

4. FIRE PREVENTION.

The basis of fire prevention is the elimination of the hazard, and in ships generally a determined effort to reduce inflammable material can go a long way towards this aim. It is desirable that materials should meet the requirements of B.S. 476 (discussed later) as regards incombustibility, and where this cannot be achieved, wood and fabrics should be given a fire-retardant treatment wherever possible. The shipbuilder to-day has at his command a choice of fire-retarding materials to provide a reasonable immunity of structure, but this requires to be supplemented by a discriminatory use of suitable material elsewhere.

Fire retardant paints are commercially available and are referred to in the chapter on *Fireproofing*. Deck coverings such as linoleum, carpets and matting will burn or smoulder if the deck approaches red heat, but their location absolves them from consideration as a major hazard. To avoid adding to fire-intensity, however, it might be desirable to use a material of a magnesite

base which would be relatively incombustible. Stage curtains should be of asbestos or similar material, or be thoroughly fireproofed. There should be no difficulty nowadays in providing insulating materials of asbestos of something equally resistant to fire, such as fibre glass, glass wool, slag wool, etc. In modern ships the use of metal furniture further reduces the fire hazard.

The Merchant Shipping (Construction) Rules, 1952 (see Chap. 5), require deck sheathing to be not readily ignitable ; prohibit the use of paints, varnishes, etc., which contain a nitro-cellulose base, and fabrics containing nitro-cellulose ; and require the use of wood to be kept to a minimum in the construction and equipment of galleys, bakeries and main pantries.

Fire prevention in H.M. Ships follows much the same line but pursues it more rigorously. Even so, in the interests of habitability the result must be a compromise. Where wood must be used it is fireproofed by an impregnation process. Exceptions to this are spars, and wood which is specially liable to come into contact with food. Mess tables are, however, fireproofed. Fire-retardant paints are used, and furniture generally is of metal. Insulating materials are asbestos based, or of glass wool. Ship's side linings are not now fitted, the insulating material being applied to the steelwork. Fabrics are, wherever possible, fireproofed in a solution of borax and boric acid in water, in the proportions of 10 ozs. of borax and 8 ozs. of boric acid to one gallon of water. As the deposits are water-soluble, reproofing is necessary whenever the material has been laundered or exposed to damp. The use of glass wool fabrics was considered, but their low abrasion resistance operated against them. Clothing, bedding, stationery, etc., are, wherever possible, stowed in metal lockers with positive closure doors.

Fire prevention is assisted by keeping bilges free of oil accumulations, by heat insulation, ventilation of compartments where inflammable vapours may collect, the protection of electric circuits, the use of flameproof electrical equipment where necessary, etc. Finally, where a fire hazard must be accepted, regulations are framed with a view to directing attention to its unavoidable dangers and the best ways of overcoming them.

5. FIRE PROTECTION REGULATIONS RELATING TO MERCHANT SHIPS.

The Ministry of Transport is responsible for all matters relating to safety of life at sea, and carries out inspections to ensure compliance with the regulations.

Prior to November, 1952, these were contained, for the most part, in so far as fire protection was concerned, in the 1929 Safety

Convention and the Merchant Shipping (Fire Appliances) Rules, 1948, which have now been superseded by the Merchant Shipping (Construction) Rules, 1952, and the Merchant Shipping (Fire Appliances) Rules, 1952. Both these documents cover requirements, which in the opinion of the M.O.T., are necessary to implement the provisions of the International Conference for the Safety of Life at Sea, 1948. They came into force on the 19th November, 1952. The first is applicable to British passenger ships, the second to British ships and craft generally except certain pleasure yachts. Warships do not come within the scope of the regulations.

Generally speaking, the 1952 Rules add little to the 1948 Rules in the way of fire detection and extinguishing. A noteworthy addition is the acceptance of high pressure water spray systems in the machinery spaces of certain passenger and cargo vessels. The regulations relating to the distribution of pumps and their power supplies are also tightened up.

On the construction side, the 1929 Safety Convention introduced important regulations relating to fire protection, requiring in passenger ships the provision of automatic fire alarms; and fire resisting bulkheads above the bulkhead deck, in general not more than 131 ft. (40 metres) apart. These bulkheads were to extend from side to side of the ship, and in association with the main watertight bulkheads were intended to create a number of sections each capable of containing a fire. The bulkheads were to be capable of resisting a temperature of 1500°F. for one hour. The 1948 Safety Convention, on which is based the 1952 Construction Rules, marks an important advance in regulations relating to passenger ships, for which it lays down three alternative methods of fire protection. Each method retains the system of fire resisting bulkheads about 131 ft. apart. Also common to each is the requirement for the protection of main stairways by fire resisting boundaries, so as to maintain an escape route for passengers and crew, and provide access for firefighting parties, as well as to prevent spread of fire by draught. Details regarding fire protection as regards all matters apart from fire appliances are given in the 1952 Construction Rules, which also include detailed requirements for an automatic sprinkler installation and for film shows on board.

The three methods approved in the 1952 Construction Rules are applicable to accommodation and service spaces. Briefly they are as follows :—

Method I. "B" class (see Chapter 7) internal divisional bulkheads must be fitted, together with an automatic fire alarm and fire detection system. This is essentially an American arrangement.

Method II. The fitting of an automatic sprinkler, fire detection, and fire alarm system, generally with no restriction on the

type of internal divisional bulkheading. This method is normally found in British and some Continental ships.

Method III. Sub-division by "A" and "B" class (see Chapter 7) divisions, plus an automatic fire alarm and fire detection system and a restriction on the provision of combustible material. This is essentially a French arrangement.

Ships not carrying more than 36 passengers need not comply with the requirements as to accommodation and service spaces, provided these spaces have a fire detection system. They must, however, comply as to main fire resisting bulkheads 131 ft. apart.

In ships built to Method I and carrying more than 100 passengers, "B" class divisions must be of incombustible (as defined in B.S. 476—see Chapter 6) materials, which may, however, be faced with a certain thickness of combustible material; and all linings, grounds, ceilings and insulation (except in cargo and similar spaces) must be of incombustible material. In vessels carrying not more than 100 passengers, the linings, etc., need not be of incombustible material provided they conform to a certain fire-resistant standard.

The broad requirements of the 1952 Fire Appliances Rules, in so far as they appear to apply to large ocean going vessels, are summarised briefly below. No attempt has been made in these pages to go into details, for which the reader must refer to the rules themselves.

(1) Cargo Spaces.

A fire alarm or fire detection system registering at suitable points must be fitted in passenger ships.

A fixed smothering gas installation is required in passenger and cargo vessels. If CO_2 is used, the installation must be capable of providing a minimum quantity of free gas equal to 30% of the gross volume of the largest hold which is capable of being sealed. Steam may be accepted as an alternative, provided there is available an evaporation of at least 1 pound of steam per hour per 12 cubic feet of the gross volume of the largest hold space. In tankers, the steam or gas installation must discharge over the surface of the cargo; and in these vessels a fixed foam installation may be fitted instead of one employing gas or steam. Holds in cargo vessels (but not the tanks of a tanker) may be exempted :—

(*a*) if they are provided with steel hatch covers and can effectively be sealed;

(*b*) in vessels built and used as ore carriers and colliers;

(*c*) if the vessel is engaged on short voyages.

Proviso (*c*) applies to holds in passenger ships.

(2) Machinery Spaces.

In passenger and cargo vessels *which have oil fired main or auxiliary boilers* there must be :—

(*a*) a foam installation capable of covering the boiler rooms and any space which contains the whole or part of the oil fuel installation, to a depth of 6 inches, on the basis of the largest single area over which oil fuel is liable to spread in the event of a leakage. Control of the installation must be from a readily accessible position not likely to be cut off in the event of a fire. If the engine and boiler rooms are not entirely separate, the whole is to be considered as one compartment. Smothering gas or high pressure water spray may be used in passenger ships as an alternative to foam ; and smothering gas or steam or high pressure water spray as alternatives to foam in cargo vessels, with the proviso that if steam is used in cargo ships which have only water-tube boilers, there must be additionally a 30 gallon foam (or 100 lbs. CO_2) extinguisher. If CO_2 is used in boiler rooms, the installation must be capable of producing a quantity of free gas equal to 30% of the gross volume of the largest boiler room measured to the top of the boilers, the engine room and boiler room to be considered as one compartment if they are not entirely separate.

(*b*) At least 2 portable foam extinguishers in each firing space in each boiler room, and in each compartment containing the whole or part of the oil fuel installation, plus in cargo ships a 10 gallon foam (or 35 pounds CO_2) extinguisher in each boiler room with more than 5 burners, or if less than 5 burners, a 2 gallon foam extinguisher per burner.

(*c*) A receptable containing at least 10 cubic feet of sand or other suitable dry medium in each firing space.

In passenger ships which have *oil fired main or auxiliary boilers* there must be additionally one 30 gallon foam (or 100 lbs. CO_2) appliance for ships with one boiler room, two if more than one boiler room. Each extinguisher is to be provided with a reel of hose so that any part of the protected space can be reached.

In passenger vessels which have *internal combustion machinery* there must be at least one 30 gallon foam (or 100 lbs. CO_2) extinguisher in the motor room ; if, however, a similar appliance is supplied to cover an oil fired boiler, the space concerned need only have in addition a 10 gallon foam (or 35 lbs. CO_2) extinguisher. A 2 gallon foam extinguisher is also required in the motor room for each 1000 B.H.P., with a minimum of 2 and a maximum of 6.

In cargo vessels which have *internal combustion machinery* the motor room must have at least two 10 gallon foam (or 35 lbs. CO_2)

extinguishers, with the proviso that only one need be supplied if a similar appliance is fitted in the space concerned in accordance with the requirements for oil fired equipment. Additionally, between 2 and 6 foam extinguishers of the 2 gallon type, according to B.H.P., are required.

(3) Pumps.

Pumps used for fire purposes must be independently driven and must not be used for pumping oil. Their capacity must be at least two-thirds the total capacity of the bilge pumps. Relief valves are required to be fitted to prevent excessive pressure in any part of the system.

Passenger ships of 4,000 tons gross or over must have at least 3 fire pumps ; under 4,000, at least 2 such pumps.

Each pump must be capable of delivering 2 powerful jets simultaneously with at least 40 feet throw.

In a passenger ship with oil fired boilers or internal combustion machinery, the arrangements of sea connections, pumps and their sources of power, must be such that a fire in any one compartment would not put all the fire pumps out of action.

In cargo vessels with main or auxiliary oil fired boilers or with internal combustion machinery, there must be an alternative means of extinguishing the fire, if a fire in any one compartment could put all the fire pumps out of action.

(4) Hydrants, Hoses and Nozzles.

Hydrants are to be so fitted that at least 2 streams of water may be directed simultaneously into any part of the ship. In passenger ships this is to be by means of hoses from separate hydrants.

In ships with oil fired or internal combustion machinery there must be at least 2 hydrants in the machinery spaces, one port, one starboard, each with a fire hose and a spray nozzle.

Hoses are not to exceed 60 ft. Nozzles, other than spray nozzles, are not to be less than $\frac{1}{2}$ inch.

In passenger ships, equipment is to be such that 2 powerful jets can be directed simultaneously on any space used by passengers and crew, when all watertight and main fire doors have been closed ; into each cargo space ; and into any machinery or coal bunker space. There must be at least one fire hose per hydrant.

Hoses and fittings must be kept near the hydrants.

(5) Passenger and Crew Spaces.

In passenger ships, on each deck in each of these spaces there must be at least 2 portable fluid fire extinguishers. When passengers are carried in enclosed spaces above the bulkhead deck,

there must be at least 1 portable fluid extinguisher on each side of the ship in such spaces.

In cargo vessels there must be readily available 1 portable extinguisher for use in every compartment of the crew and passenger spaces. Generally, for large vessels, there must not be less than 5 extinguishers.

Extinguishers in which the medium is stored under pressure, *e.g.*, CO_2 extinguishers, are not allowed in passenger and crew spaces.

Other regulations relating to fire hazards in ships are contained in various Acts and Circulars. The Prevention and Extinction of Fires in Cargo Vessels (Board of Trade Notice No. M140) deals with dangerous goods, spontaneous combustion in coal, and oil fire risks. B.O.T. Circular 1650 discusses fire prevention in association with the hazard of oil fuel. Regulations in M.O.T. Circular 1816/1947, and the Merchant Shipping (Dangerous Goods) Rules, 1952, define conditions of stowage of dangerous goods in ships. The carriage of explosives is governed by M.O.T. Circular 1817/1947. Repair work on ships which have carried oil or spirit, either as cargo or bunkers, comes under the Shipbuilding Regulations 1931.

6. FIREPROOFING AND FIRE RESISTANCE TESTING.

Fireproofing.

The general aim of fireproofing is to ensure that materials so treated will neither assist in the development of a fire nor in its spread. To some extent the term fireproofing is misleading, since materials cannot be rendered "proof" against a fire which has developed. But as applied to timber and textiles, it implies a treatment with suitable deposits which increases resistance to fire so that they become incapable of propagating flame.

Timber plays an important part in most buildings and is used extensively in ships. It cannot be rendered incombustible, but can be prevented from flaming or glowing. The most effective method, which has given very satisfactory results, is impregnation under pressure with an aqueous solution of mon-ammonium phosphate containing a small proportion of boric acid. The wood is first dried to ensure penetration of the proofing medium, and then placed in the solution in a closed vessel, air pressure being applied to the liquid surface. Wood so treated will ultimately char through if heat is sustained, but will not flame unless it is splintered. It will, however, evolve a considerable amount of smoke. Under standard fire test conditions, defined by B.S.S. 476, timber doors of Canadian red pine treated in this way have qualified

for Grade D classification, equivalent to that required for a Class A division under the terms of the 1952 Construction Rules. Most of the timber, including plywood, supplied in recent years for H.M. Ships has been fireproofed by the impregnation process. Wood so treated is more difficult to work than untreated timber since it contains crystals of mon-ammonium phosphate. Good practice would be to fireproof in finished sizes. The treatment of plywood does not impair the adhesive strength of the layers.

Experience has shewn that in a fire, treated timber may last a little longer than untreated. The difference is not, however, appreciable. The value of fireproofing lies in the fact that, besides providing a means of resisting fire development, it ensures the minimum contributory effect.

A less effective method of fireproofing is brush application of the medium, the principal fire retarding chemicals in water-base paints being borax, sodium silicate and mon-ammonium phosphate. These coatings are non-inflammable and persist even at high temperatures. They are, however, soluble in water and leach out on exposure to the weather. They do not afford much resistant protection in an intense fire.

Textiles.

The fireproofing of textiles involves a treatment with inhibitors, mainly salts of inorganic acids and metallic oxides, which render the fabric incapable of supporting flame. The medium used modifies the process of decomposition, which will occur thereafter at a temperature lower than the ignition temperature of the vapours evolved. Owing to the large volume of smoke generated during decomposition, the application of the process to fabrics for use in ships tends to be somewhat restricted.

There is no known fireproofing solution that is permanent and does not affect the texture. A large number of processes is listed in the appendix to "The Fireproofing of Fabrics" published by H.M. Stationery Office in 1947. They have been developed primarily for cotton fabrics, which possess a very high fire hazard. Linen, hemp, and jute fabrics also have this disability but burn rather more slowly. Artificial silk is as hazardous as cotton, Woollen and silk fabrics possess to a certain extent natural fire resistant qualities.

Substances which have proved effective as fireproofers include sodium tungstate, borates, sulphates, phosphates, silicates, certain ammonium salts (particularly the phosphates), carbonates, aluminium or zinc salts, zinc chloride, compounds of metals such as antimony, bismuth and tin, etc.

Most fireproofing processes lose their protective value when the fabric is exposed to damp or to the open air. The majority consist simply of immersing the fabric in a solution of a suitable

salt, wringing out and drying. Water soluble deposits, which are inexpensive to apply, are not suitable where a higher degree of permanence is desired, as for hangar canvas, deck awnings, etc., or to articles generally which require repeated laundering. In these cases, fireproofing is carried out with insoluble deposits, usually metallic oxides, which increase the weight of the fabric considerably as compared with soluble treatments.

Paint.

It is a well-known fact that fire can be propagated from one compartment to another in a ship by means of the paint film on the steel bulkhead. A rise in temperature on the unexposed side, as a result of a fire in the adjoining space, leads to the formation of blisters containing inflammable vapours arising from any organic paint medium in the paint layer. When the temperature is sufficiently high, the blisters burst and the vapours ignite spontaneously. They burn with great vigour, and will transmit the fire to any combustible which is sufficiently near.

There are a number of good fire retardant paints on the market, including tumescent types, which under heat conditions swell to form a frothy insulating mat which protects the surface. Retardant coatings for unpainted timber not exposed to the weather include sodium silicate and strong solutions of mon-ammonium phosphate or di-ammonium phosphate.

The requirements of habitability, appearance, etc., generally make it necessary to use an oleo-resinous medium, and broadly speaking, the degree of retardance depends upon this being kept to a minimum. The number of coats should also be kept to a minimum consistent with good application. It is not possible to get a really good high-gloss fire-retardant paint which is formulated on normal oleo-resinous bases. It is, however, possible to formulate such a paint on a chlorinated rubber base.

Research is being carried out on the use of cementiferous paints which are completely inorganic and incombustible. One type consists essentially of a zinc oxychloride cement containing a large amount of metallic zinc. These paints have a use as an anti-corrosive, but difficulties regarding appearance have to date prevented their general adoption for internal work.

Fire Resistance Testing—B.S.S. 476.

The basis of modern fire resistance testing in this country is British Standard Specification No. 476, the full title of which is "British Standard Definitions for Fire Resistance, Incombustibility and Non-Inflammability of Building Materials and Structures." It was issued in 1932. An addendum dated July, 1945, added to the Standard a "spread of flame" test.

B.S. 476 makes it possible to assess experimentally on an arbitrary basis, simulating actual fire conditions, the behaviour of an element of structure. The tests are applicable to ship and aircraft bulkheads as well as to partitions in buildings.

The requirements of a structure in a fire are that it shall not readily ignite or contribute to the spread of a fire, and that it shall continue to perform the function for which it was designed for the longest possible time. Fire resistance has been defined as "a relative term used to designate that property by virtue of which an element of structure as a whole functions satisfactorily for a specified period, whilst subjected to prescribed heat influence and load."

The term "Fire Resistance" is used in connection with the behaviour of a combination of various materials considered as a whole and forming a single part of a structure. To define it, a standard time-temperature curve was evolved, representative of actual fire conditions, whose ordinates are as follows :—

1000°F.	after	5	minutes	1850°F.	after	2	hours
1300°F.	,,	10	,,	2050°F.	,,	4	,,
1550°F.	,,	30	,,	2200°F.	,,	6	,,
1700°F.	,,	60	,,				

A significant feature of the curve is the rapid rise in temperature during the first few minutes.

The curve has become the standard scale for measurement of fire test severity. When elements of structure are tested, furnace temperatures are controlled to conform to it. The standard requires elements to be tested full size under conditions of restraint and loading as defined, to represent as nearly as possible its functions in service. Full scale tests are made because of the unreliability of small scale experiments in relation to subsequent behaviour under real fire conditions. The element of structure is subjected on one side to regulated furnace heat, and receives a grading according to the time under test without failure. No cracks or fissures must develop, it must not collapse, and the temperature on the unexposed face must remain below a stipulated maximum. In some cases an impact test is applied to eliminate types of construction which might pass the fire test but which might fail under actual fire conditions if slightly damaged physically. Specimens are classified in one of the following grades of fire-resistance .

Grade A,	protection	against	fire	for	6	hours
Grade B,	,,	,,	,,	,,	4	,,
Grade C,	,,	,,	,,	,,	2	,,
Grade D,	,,	,,	,,	,,	1	hour
Grade E,	,,	,,	,,	,,	½	,,

Materials.

Tests are laid down in B.S. 476 to cover requirements for incombustibility, inflammability, and rate of surface spread of fire.

An incombustible material is defined as one which, when subjected to heat conditions reaching a temperature of 750°C. (1382°F.), neither burns nor gives off inflammable vapours in sufficient quantity to ignite at a pilot flame. Any material failing to pass the test is regarded as combustible.

Inflammability is rather lower in the scale, and is a measure of the readiness to ignite. There are 3 grades (*a*) non-inflammable; (*b*) very low inflammability, and (*c*) low inflammability. A non-inflammable material may yet be combustible. Materials are tested under controlled conditions, the underside being subjected to a flame for a certain period, and the time for which the specimen glows or flames after the extinction of the test flame, is noted. Measurements of the charred or scorched area are made, and these determine the category of inflammability.

The Rate of Surface Spread of Flame is intended to differentiate between the rates at which flame will spread over the surfaces of various combustible types of wall linings and ceilings, taking into account the effect of radiant heat, and has an important bearing on internal building construction. This test is used for grading fire-resistant coatings, and has been adopted in the 1952 Construction Rules to cover requirements for concealed surfaces in passenger ships.

Application to Ships.

The 1948 Safety Convention has adopted the British Standard definition of incombustibility, and the standard fire test, and they are included, together with the rate of surface spread of flame test, in the 1952 Construction Rules. The rules require from fire resisting divisions nothing more severe than one hour's endurance of the standard fire, so that any division or element of structure which acquires a Grade D classification, qualifies for a Class A fire-resistant division, which would be a main bulkhead or its equivalent in importance. Those classified as Grade E are satisfactory for Class B divisions, which are divisional bulkheads and sub-divisions generally between main bulkheads.

---

7. FIRE RESISTANT BULKHEADS AND DOORS.

(1) Bulkheads.

Requirements for future ships will be based on the regulations laid down in the 1948 Safety Convention, as interpreted by the 1952 Construction Rules, which are much more rigidly defined than those existing previously.

Class A Fire Resistant Divisions are decks and bulkheads which, broadly speaking, comply with the following conditions :—

(*a*) to be of steel or equivalent material and to be suitably stiffened.

(*b*) to be capable of preventing the passage of flame and smoke for one hour of the Standard Fire Test.

(*c*) generally to be insulated so that if either face is exposed to the Standard Fire Test for one hour, the average temperature on the unexposed face will not increase by more than 250°F. above the initial temperature, nor should the temperature at any one point rise more than 325°F. above the initial temperature.

Class B Fire Resistant Divisions must be capable of withstanding the passage of flame for ½ hour of the Standard Fire Test. Generally, where such bulkheads form divisions between the cabins, they must be capable of preventing, during the whole of a ½ hour Standard Fire Test, the temperature on the unexposed face from increasing by more than 250°F. above the initial temperature, nor shall the temperature at any point rise more than 325°F. above the initial temperature. If the materials are incumbustible, this requirement need only apply over the first 15 minute period, but the test must be completed in so far as other requirements are concerned.

Construction of Types of Fire Resistant Bulkheads.

There are a number of firms which specialise in this class of work and the author is indebted to those named below for permission to include the details given.

(*a*) Messrs. Pyrok, Ltd., Newcastle Wharf, 40-42 Nine Elms Lane, London, S.W.8, employ *Pyrok*, which is a form of exfoliated vermiculite (heat treated granulated mica) mixed with lime and cement. Application is by means of a *Pyrok* patented process using a special machine and gun operated by compressed air. Before it is applied, special studs are welded to the bulkhead to secure 1 inch mesh galvanised wire. The mesh ensures that the *Pyrok* is held in position under the most adverse conditions, and offers very little impediment to its application. It is essential that the plating, prior to spraying, is free from rust, millscale, paint or grease.

A test bulkhead protected with approximately 1 inch of *Pyrok*, at 45 lbs. per cubic foot, on both sides, fulfilled all the conditions for Class A Fire Resisting Divisions.

(*b*) Various firms under licence from Messrs. J. W. Roberts, Ltd., Armley, Leeds, use *Sprayed Limpet Asbestos*. This material is incombustible and its use for general insulation purposes is widespread.

It is blown on in a semi-plastic condition to form a continuous jointless layer of asbestos felt, in intimate contact with the steel plates and stiffeners. Surfaces must be scraped and cleaned by wire brushing before fixing, heavy scale being first loosened by chipping. Priming paint and a primary adhesive emulsion are recommended by Messrs. Roberts, Ltd., but are not essential to meet fire-resistant requirements for Class A or B divisions. Mild steel clips, preferably of 15 W.G., are welded to the plating, and wires threaded round them provide a reinforcement for the cement finish. The clips are not necessary in normal insulation work. After the fibre is pressed down to the required thickness and has set, asbestos cement is trowelled on, finished smooth, and all corners rounded. Fig. 1 shews a typical securing arrangement under a deck. Similar arrangements will apply as regards bulkheads.

S.L.A. can be used for bulkheads where the necessary strength and rigidity are provided by the bulkhead itself. A specimen

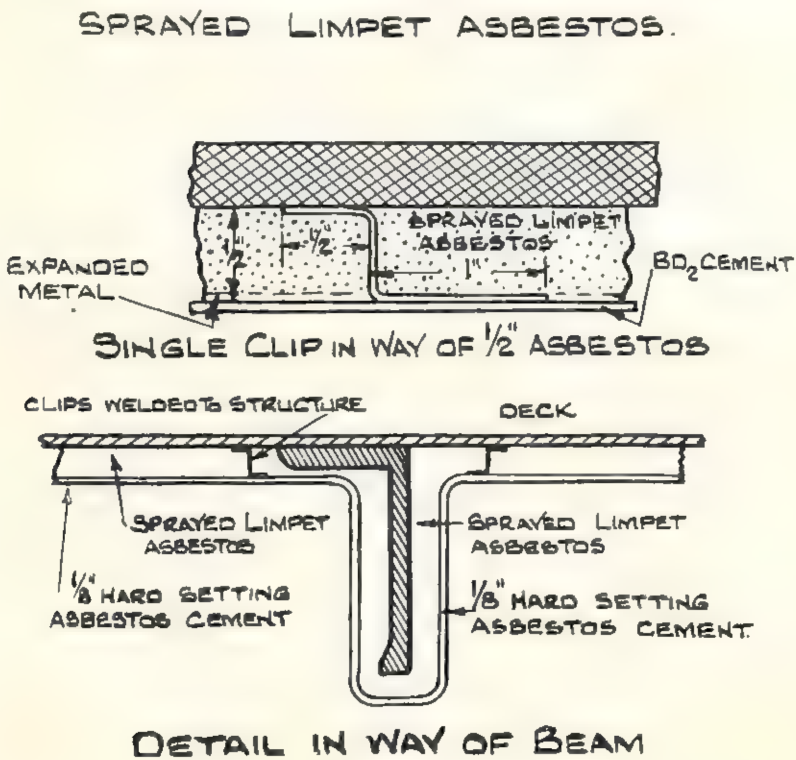


Fig. 1.

lined with ½ inch S.L.A. on the heated side and plywood on the other, satisfied under test the requirements for Class B divisions.

Another specimen faced on both sides with ½ inch S.L.A. with a plywood finish on the unexposed side, satisfied Class A requirements. The weight of the material with a cement facing is about 22 ounces per square foot for a thickness of ½ inch.

S.L.A. also has applications for insulation under decks, and to engine and boiler room casings, and for acoustic insulation.

(*c*) The development and use of *Marinite* (Messrs. Marinite, Ltd., Park Street, London), must constitute one of the most important advances for fire resisting structures generally. It is an incombustible sheet material made of asbestos fibre with an inorganic binder, and weighs 35 lbs. per cubic foot. It does not suffer from mould or fungus, and will not harbour vermin. Over 20 million square feet are already installed in American ships. It is, at the moment, one of the few substances which can be used

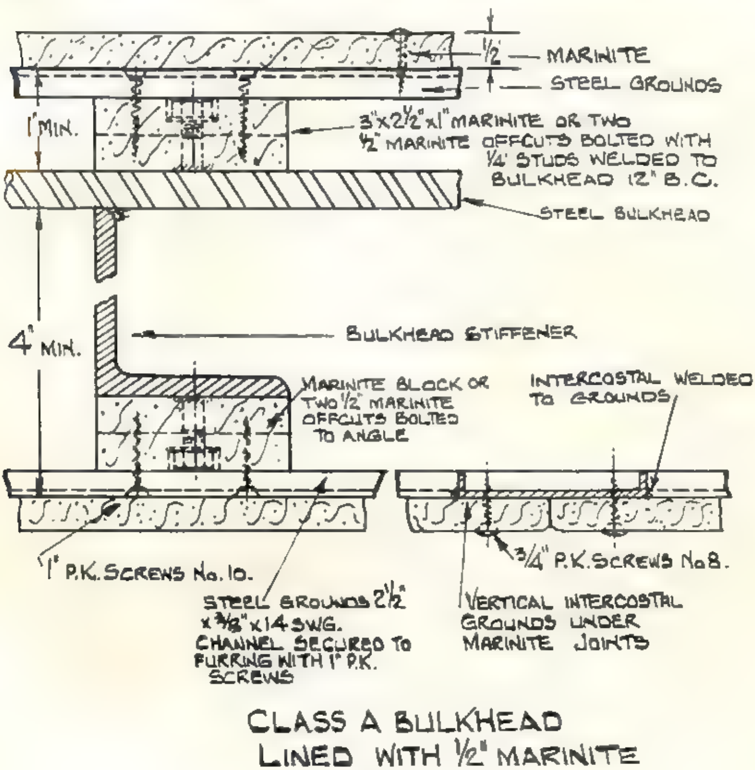


Fig. 2.

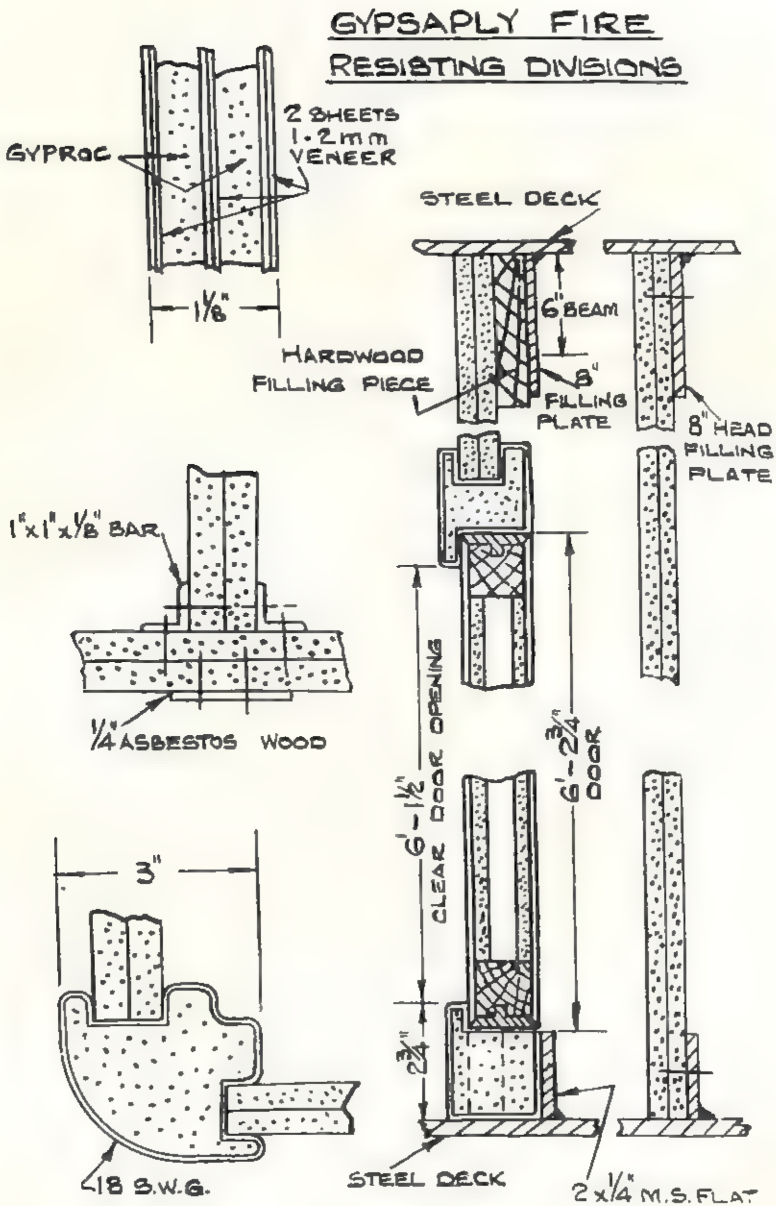

GYPSAPLY FIRE
RESISTING DIVISIONS
GYPROC
2 SHEETS
1·2mm
VENEER
1⅛"
STEEL DECK
6" BEAM
HARDWOOD
FILLING PIECE
8" FILLING PLATE
8" HEAD FILLING PLATE
1"x1"x⅛" BAR
¼" ASBESTOS WOOD
6'-1½" CLEAR DOOR OPENING
6'-2¾" DOOR
3"
2¾"
18 S.W.G.
STEEL DECK
2x¼" M.S. FLAT

Fig. 3.

for the protection of aluminium when used as decking or bulkheading.

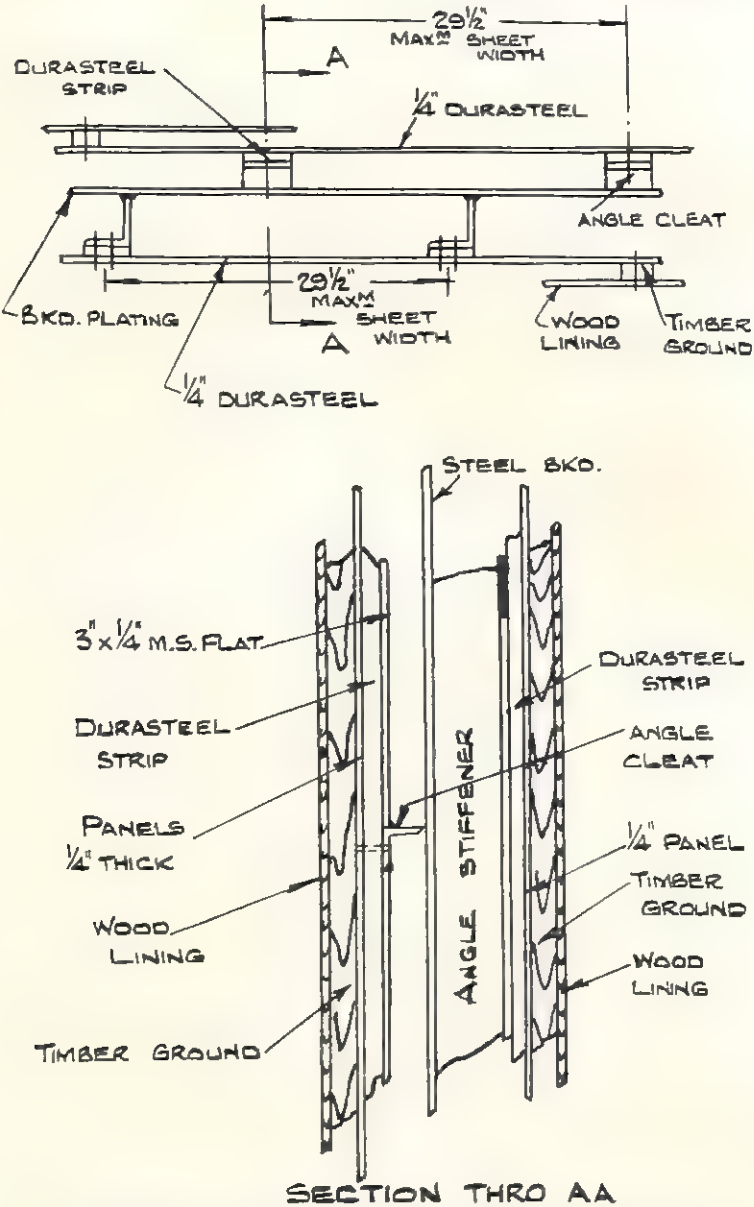
Marinite is readily worked and possesses intrinsic rigidity. A ship's bulkhead of panels $\frac{7}{8}$ inch thick has satisfied test conditions for Class B Fire Retardant Divisions. Fig. 2 shews the arrangement on a bulkhead to satisfy 1 hour of the Standard Fire Test conditions for Class A Fire Resistant Divisions. The M.O.T. has decided that where *Marinite* is used throughout in British ships carrying more than twelve passengers, the installation of sprinklers is unnecessary.

Designed primarily for use as a divisional bulkhead and shipside lining, and for fireproofing the underside of decking without supplementary insulation, Marinite has applications in cabins and public rooms, etc.

(*d*) Flexo Plywood Industries, Ltd., South Chingford, London, E.4. produce *Gypsaply*, of which the basic material is a special lightweight gypsum faced in gaboon veneer. Additionally it may be faced with a decorative veneer, sheet metal or one of the laminated plastics such as Warerite or Formica. Approval has been given by the M.O.T. for the use of *Gypsaply*, in a thickness of $1\frac{1}{8}$ inches, for Class B divisions, in ships carrying not more than 100 passengers. The material is easily worked and adequate fixing for all fittings is obtainable by using self-tapping screws. A 1 inch No. 10 P.K. screw in a $1\frac{1}{8}$ inch bulkhead, sustained a load of 220 lbs. before failure. The weight of the material is 42 lbs. per cubic foot. Typical arrangements are shewn in Fig. 3.

(*e*) Messrs. Durasteel, Ltd., Greenford, Middlesex, are the makers of *Durasteel*, which is a composite asbestos and steel sheeting. It was produced primarily for building construction, but a number of Durasteel fire resisting doors of the "Fireman" pattern (as tested and approved by the Fire Offices' Committee) have been fitted in ships. The use of *Durasteel* as fireproof cladding to Class A divisions has been approved by the M.O.T., Fig. 4 shews a typical arrangement.

(*f*) Stillite Products, Ltd., Kingsway, London, W.C.2, market *Stillite*, which is made of mineral wool with an organic binder, in semi-rigid slabs. Some sort of finish is essential, either of plywood or hardwood, fitted on timber grounds. In addition to its excellent properties as a fire resistant medium, it is useful for thermal or acoustic insulation. The material is non-corrosive, and nails and screws can readily be driven into it. As a result of tests carried out on a specimen bulkhead, the M.O.T. has approved its use on steel bulkheads to form Class A divisions, with a thickness of 1 inch of *Stillite* on each side. The weight of the material is 13 lbs. per cubic foot. Fig. 5 shews a typical arrangement.



PROTECTION OF DECKS AND BULKHEADS BY DURASTEEL.

Fig. 4.

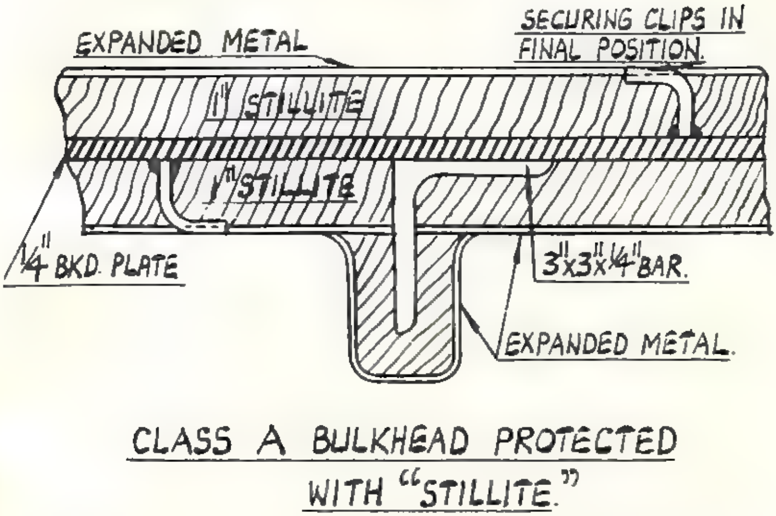


Fig. 5.

The semi-rigid slabs are cemented to the steel plating with a cold setting adhesive. Securing clips are welded to the bulkhead. The slabs are overlaid with expanded metal, the whole being tightened down by bending over the clips.

(2) Doors.

Under the 1952 Construction Rules, doors are required to possess a degree of fire resistance at least equal to that of the respective bulkheads in which they are fitted. They must be capable of being opened from either side by one person, and are required to be self-closing with simple release from the open position. Fireproof doors usually have a locking mechanism engaging at 3 points by means of a triple acting espagnolette type bolt. Watertight doors need not be insulated.

Difficulties have arisen regarding the application of the regulations to some types of doors, specifically with those incorporated in Class A divisions, where the standard of the door and its structure should be such as to maintain that of the bulkhead itself. Whilst the door leaf itself may present no great problem, the framework, when it is of angle sections or similar, is susceptible to heat conduction. It is stated that to design the frame in non-conducting material in these cases would lead to prohibitive practical difficulties. In practice, the M.O.T. have so far compromised by accepting the normal steel frames, but stipulating a clearance in each case between any combustible material and the door frame.

B.S. 459, Part 3, 1946, "Fire Check Flush Doors (30 minute type)" lays down requirements for an economical type of flush door, presumably for use in buildings, which when subjected to the standard fire test will act as an effective barrier for 30 minutes. The doors are of combined timber and plywood construction. A minimum finished thickness of $1\frac{3}{4}$ inches is stipulated. A protective filling of $\frac{3}{8}$ inch plasterboard conforming to B.S. 1230 Gypsum Plaster board, is also required. No reference is made in the B.S. to fireproofing.

The Fire Offices' Committee also lays down rules for the construction and fixing of fireproof doors, compartments, and shutters, of composite materials. The product of a number of firms has been approved by the Committee.

8. FIXED INSTALLATIONS.

(1) Fixed Extinguishing Installations.

(a) Automatic and Non-Automatic Sprinkler Installations.

The Automatic Sprinkler System, as used in commercial practice and in many passenger ships, is by far the most important and efficient of all fire protection devices, and until its development, very little headway was made in reducing fire losses.

The earliest attempt at automatic fire protection was a perforated pipe system, the operating valve being kept closed by a piece of taut string, which burnt through when a fire occurred.

Although the first sprinkler head to be recognised by the insurance companies was one invented in 1874 by an American, Mr. Parmelee, it was not until the advent in 1882 of the "Grinnell" Sprinkler, which obtained its name from the inventor, Mr. Grinnell, another American, that Automatic Sprinkler protection achieved its purpose with any marked degree of success. The original type of "Grinnell" sprinkler head which was introduced into England in 1884, consisted in the essential parts of a yoke, a valve and a deflector plate combined, and a compound lever holding the valve in position ; the fusible metal holding the parts of the compound lever together, melting at some pre-determined temperature, allowing the valve to fall away and the issuing water to strike the deflector plate and be distributed over a considerable floor area. All modern sprinklers have been developed from that produced by Mr. Grinnell.

After World War I, the bulb sprinkler was developed. This type embodies a barrel like container made of transparent material similar to glass, but much tougher, and nearly filled with a highly expansible liquid. The valve in the sprinkler head is kept in place

in the closed position by the bulb. Heat application causes the liquid in the bulb to expand, shattering the bulb, and allowing the valve to fall away, thus opening the head. Operation can be arranged to take place at a temperature range between 155°F. and 360°F., the liquid in the bulb being coloured in accordance with a colour scheme which covers this range. The contents of the bulb are not affected by low temperature, nor is the bulb itself liable to corrosion. An illustration of the bulb type sprinkler head is given in Fig. 6.

Essentially, an automatic sprinkler installation consists of a grid of pipes suitably graded in diameter, normally just below ceiling level, connected to an efficient water supply with the necessary controlling valves. At intervals in the piping are fitted the sprinkler heads. The system is usually full of water, the valve in each sprinkler head holding back the flow. Each head that opens discharges water, which strikes the deflector plate and is

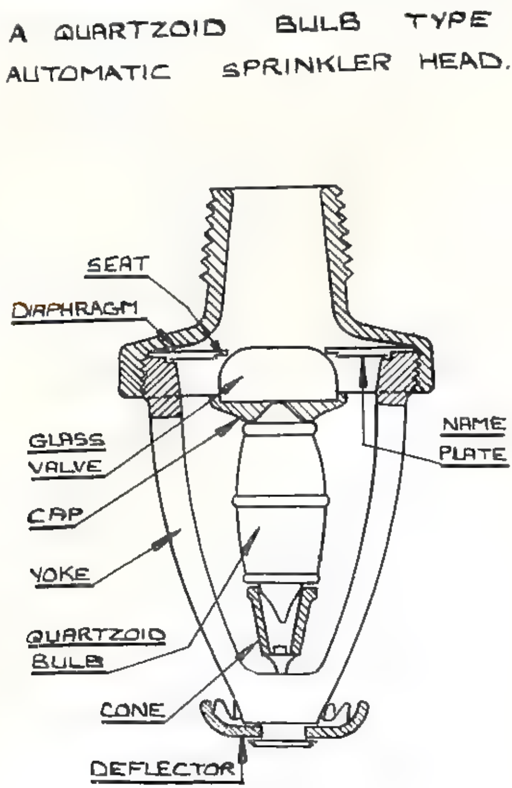


Fig. 6.

distributed in the form of a spray. Standard practice is to space the sprinkler heads approximately 10 feet apart, and this ensures coverage of the entire floor area. Sprinklers must not be placed within 2 feet of columns or beams.

Where there is a risk of frost, as in an unheated building, the system is dry back to the control valves, the sprinkler pipes being charged with air. An air pressure of about 20 lb. per square inch can be made to balance a water pressure of 160 lb. per square inch, by means of a double seated valve with a suitable arrangement of area ratio. When a sprinkler head opens, the air is released, the control valve is opened, and water flows to the sprinklers.

In this country, the standard orifice of a sprinkler head is $\frac{1}{2}''$, and a minimum pressure of 5 lb. per square inch is required for satisfactory performance. At 10 lb. per square inch, the rate of discharge is 12 gallons per minute; at 15 lb. per square inch, 15 g.p.m. and at 30 lb. per square inch, about 22 g.p.m. All sprinklers have a male thread $\frac{1}{2}''$ B.S.P. 14 T.P.I.

Protection by an automatic sprinkler system means early detection and attack. The number of heads opening depends on the extent of the fire. Such installations have proved their worth at many fires, and this is reflected by the outstanding rebates, seldom less than 50% and frequently as high as 70%, allowed by insurance companies to concerns which have fitted them in their premises. The Fire Offices' Committee lays down minimum standards necessary to secure rebates of premiums, including a standard for water supply.

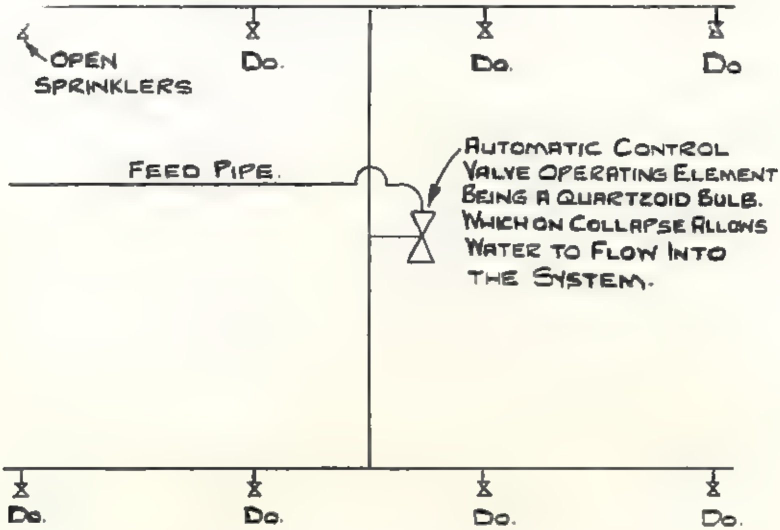
Normally an automatic installation should have two independent water supplies, one of which should be inexhaustible. In spite of the obvious importance of ensuring adequate supplies of water to the installation, there have been cases where the sprinkler equipment has been rendered practically useless by tapping the supply to feed hydrant installations or pumps feeding them.

In most systems the flow of water occasioned by the opening of a sprinkler head or heads is utilised to operate an alarm valve, which, in turn, causes a bell to ring, thus giving an immediate warning of the outbreak of fire.

Sprinkler installations have a very wide application in industry and commerce, including mills, factories, grain elevators, saw mills, departmental stores, hotels, restaurants, warehouses, etc.

Under certain circumstances, as in a tannery, where hides require to be hung in drying rooms, it is essential to ensure that the water is well distributed amongst the hides. This is effected by the use of the *multiple jet system*, which consists of a number of groups of not more than 8 specially designed open-type (non-automatic) sprinkler heads, each group being operated by a control which has a sprinkler bulb as the detecting element. The piping is charged with water up to the control, the pipework grid containing

the open heads being dry. When the temperature reaches the operating temperature of the bulb, the bulb shatters, allowing the water to lift the valve, and to pass simultaneously to the open sprinkler heads connected to that particular control. A diagrammatic arrangement is shewn in Fig. 7.



DIAGRAMMATIC REPRESENTATION OF A MULTIPLE JET SPRINKLER SYSTEM.

Fig. 7.

In Merchant Ships.

The 1952 Construction Rules lay down three alternative methods of protection for accommodation and service spaces in passenger vessels : one of these methods is the fitting of an automatic sprinkler and fire alarm system. The sprinkler system must be of the wet type.

The automatic sprinkler system on board a passenger vessel is divided into a number of sections to suit the arrangement of the watertight and fireproof bulkheads, such division facilitating the early location of the outbreak of fire, and largely avoiding the necessity of piercing bulkheads for the passage of sprinkler pipes.

Each section has its own automatic alarm switch which is actuated by the flow of water to the sprinkler head or heads that have operated, the alarm being registered by the ringing of a bell

and the illumination of a lamp on an indicator panel, usually situated on the navigating bridge.

The water supplies to the sprinkler equipment consist of a pressure tank of suitable capacity half-filled with fresh water, the remainder with air under pressure, and an automatically operated electrically driven centrifugal pump drawing water from the sea, brought into operation by the fall in pressure in the equipment to a pre-determined level. The 1952 Construction Rules require the arrangements to be such as to prevent the pump passing sea water into the pressure tank. The pump must be capable of maintaining 25 p.s.i. at the level of the highest sprinkler. Sprinkler heads must not be more than 13 ft. apart, and not more than $6\frac{1}{2}$ ft. from a bulkhead.

The water supplies are connected to a trunk main which runs practically the full length of the ship on one of the lower decks, and from which are taken the connections to the valves controlling the various sections. There are also provided, fore and aft, shore connections to enable the sprinkler equipment to be fed by water from the shore mains or fire brigades when the vessel is in port, and when the tank and pump are undergoing their periodical survey.

A diagrammatic arrangement of an automatic sprinkler equipment on a passenger ship is shewn in Fig. 8.

In H.M. Ships, sprinkler systems are fitted in magazines and similar compartments, in the hangars of aircraft carriers, and in the cargo holds of certain L.S.T.s. As action damage might lead to premature opening of sprinkler heads, and in view of the patrol system which is a feature of warship organisation, the systems are non-automatic, employing $\frac{1}{2}''$ open orifice sprinklers each with a flat-star deflector plate.

Magazine systems are fed from the firemain, operation of the spray valve being arranged locally, and also at a remote position by means of rod gearing.

The sprinklers in the hangar of an aircraft carrier, are fitted to grids at the crown, and are spaced 10 to 12 feet apart to allow ample overlapping of water coverage. Water is supplied by a number of single speed electrically driven centrifugal pumps sited below the waterline, and operated by switches from the hangar access lobbies and the hangar control position. The pumps deliver into a main which is in a protected position, with risers to the spraying grids. Control of the spray valves is by handwheels in the access lobbies. Pump performance is sufficient to allow concurrent spraying of any two hangar sections, with an average pressure of 15 p.s.i. at the sprinkler heads. Flushing arrangements are fitted to the main to allow the system to be flushed through for the purpose of preventing an accumulation of marine growth, and to enable the pumps to be tested. A sight drain is led from the discharge side of each spray valve to detect leakage past the valve.

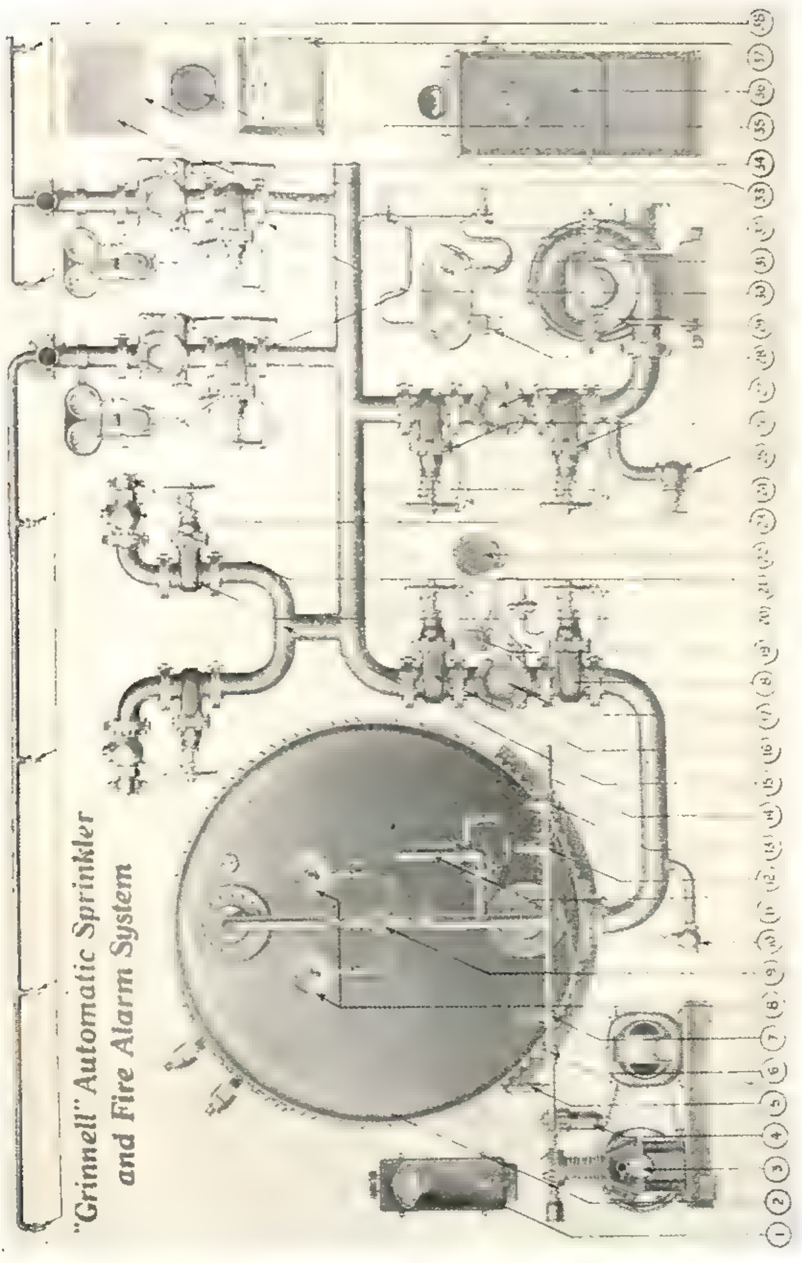


Fig. 8.

KEY TO FIG. 8.

1. Compressor Starting Panel.
2. Pressure Tank.
3. Air Compressor.
4. Oil Extractor.
5. Compressor Safety Valve.
6. Compressor B.P. Valve.
7. Compressor Stop Valve.
8. Pressure Tank Pressure Gauges.
9. Pressure Tank Water Level Indicator.
10. Pressure Tank Drain Valve.
11. Pressure Tank Safety Valve.
12. Fresh Water Supply Stop Valve.
13. Fresh Water Supply B.P. Valve.
14. Fresh Water Feed.
15. Shore Connections.
16. Pressure Tank Delivery Stop Valve.
17. Pressure Tank Delivery B.P. and Alarm Valve.
18. Pressure Tank Delivery Stop Valve.
19. Pressure Tank Alarm Switch.
20. Shore Connection Stop Valve.
21. Shore Connection B.P. Valve.
22. Pressure Tank Alarm Bell.
23. Hose Adaptor.
24. Trunk Main.
25. Pump Test Valve.
26. Pump Delivery Stop Valve.
27. Pump Delivery B.P. Valve.
28. Automatic Pressure Relay.
29. Pump.
30. Installation Control Valve.
31. Automatic Relay Isolating Valve.
32. Release Valve.
33. Indicator Pilot Lamp.
34. Indicator.
35. Alarm Bell.
36. Automatic Starting Panel.
37. Diagram of Ship.
38. Sprinkler Head.

Asbestos fire curtains sub-divide the hangars into sections 120 to 160 feet long. They provide a firebreak and help to exclude air. Experience has shown that a petrol fire can be dealt with by water spray, provided there is no air supply and the mist fills the entire space.

Hangar scuppers are large to permit of rapid draining, and are fitted with elongated perforated covers to prevent choking due to debris.

(*b*) High Pressure Water Spray Systems.

Industrial premises, such as paint and varnish works, garages, electrical power stations and other buildings where inflammable liquids are stored, may employ a fixed automatic system of fire protection involving the use of the normal bulb type sprinkler head

and specially designed projectors. An essential requirement is a good supply of water at adequate pressure, since 50 p.s.i. is required at the projector.

In the "Mulsifyre" system, by Messrs. Mather & Platt, Ltd., there are two independent grids of piping. One, fitted with projectors, is arranged to cover the oil or other inflammable liquid risk involved. The other, charged with water (or air if subject to low temperature), has fitted to it bulb type sprinkler heads which act as detectors. When a fire occurs, those affected open, and this causes immediate operation of a hydraulic valve which admits water to the projector piping. It is claimed that the high velocity and energy of the spray issuing from the projectors provides sufficient mechanical agitation of the burning surface to form an emulsion which is non-inflammable, and the fire is extinguished at once. The emulsion consists of tiny globules of the liquid, each surrounded by a film of water. In some instances, manual control of the valve is preferred.

On account of the difficulty of arranging for complete coverage in a machinery space, and also because of the large volume of water and high pressure necessary, it is not easy to apply the projector system in ships. Nevertheless, boiler rooms in some vessels are fitted with protection of this type. It is not fitted in warships. The 1952 Fire Appliances Rules permit the use of a high pressure water-spraying system in the boiler room of oil fired ships as an alternative to foam.

(c) Steam Drenching.

Steam is the oldest smothering agent and was in commercial use as an extinguishing medium for many years before the development of other inerting systems, covering, amongst other hazards, inflammable liquids.

Steam is not now widely used except in cargo holds of some merchant vessels and in machinery compartments of warships. In tankers, it may be employed for cleaning out tanks, and gas-freeing petrol tanks, but it is not usually fitted for fire-fighting except in older vessels.

The 1952 Fire Appliances Rules permit the use of steam as an alternative to an inert gas in cargo spaces, provided the boiler or boilers have an evaporation of not less than 1 pound of steam per hour for each 12 cubic feet of the gross volume of the largest hold in the ship. Steam is normally available in large quantities in steam ships, and in motor ships the donkey boiler would enable requirements of an extinguishing system to be met.

Although credited with many extinctions, the use of steam has often proved unsuccessful because its limitations were not appreciated. Nowadays other types of smothering systems are preferred. Steam condenses, and an effective concentration takes

time to build up. It is lighter than air, and for this reason it might be some time before there was any effect on a fire low down. An essential requirement is a means whereby the space can be virtually sealed. Generally speaking, steam is highly effective where a plentiful supply is available and applied.

Nozzles should be directed to cover the risk, which in machinery spaces means the bilges. Control is usually by a main valve which is either slow opening or else fitted with a by-pass which must be opened first. This arrangement is to give people in the compartment time to leave. Systems may be operated automatically, using bulb type sprinkler heads in an arrangement similar in principle to that described for the water projector spray system. Suitable release equipment would stop ventilating fans at the same time.

An American publication, referring to ovens for japan, enamel and other inflammable liquids, recommends 8 pounds of steam per minute per 100 cubic feet of oven volume. Discharge through an orifice with a supply pressure not less than 15 p.s.i. is given as :—

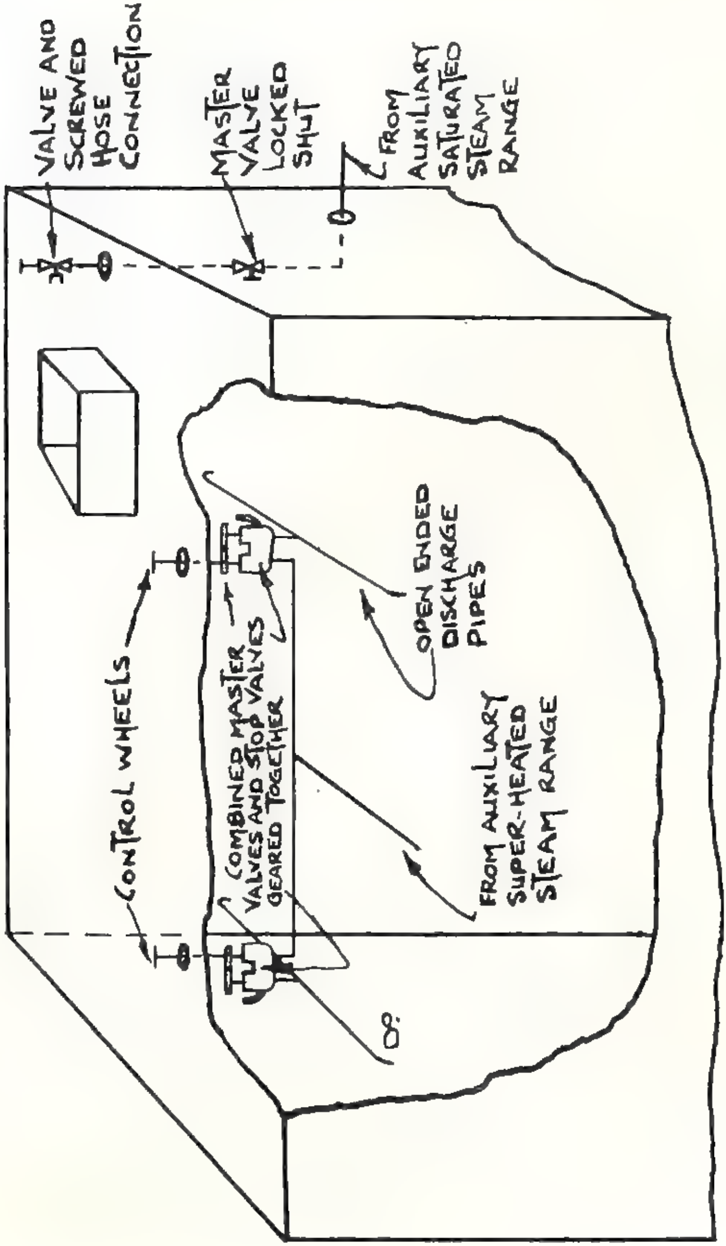
$$W = 0{\cdot}7A\ (P + 15)$$

where W = pounds of steam per minute
A = area of outlet in square inches
P = gauge pressure p.s.i.

A pound of steam per minute is equivalent to 2 boiler H.P.

It is interesting to note that iron will burn in steam. A fire occurred in a water tube boiler as the result of a failure in the supply of feed water, and continued for over five hours before it could be controlled. For the reaction to take place, iron and steam must be in contact and at a temperature exceeding 700°C. Instances are very few, and the remedy is a generous application of water to the seat of the fire to reduce the temperature. The reaction is independent of air supply and therefore cannot be dealt with by smothering. Hydrogen is evolved and may produce a secondary fire.

In H.M. Ships, steam drenching is fitted in main and auxiliary machinery compartments which have adjacent oil fuel tanks and an available steam supply. Since the contingency of flooding due to action damage must be considered, the orifices for steam injection are at the crown of the compartment. Steam is taken off the auxiliary superheated or saturated steam range, to open-ended pipes, usually 1½ inches internal diameter at the discharge end. Arrangements are made whereby the outboard ends of ventilation trunks to machinery spaces can be covered. Steam discharge is controlled by a master valve and stop valve, operated from a single hand wheel and having a warning whistle between them. The stop valve cannot be operated until the master valve is fully opened.



DIAGRAMMATIC ARRANGEMENT OF STEAM SMOTHERING

Fig. 9.

Full scale tests at the Admiralty Fire Test Ground, Haslar, have demonstrated the efficiency of such an installation, provided there is no appreciable air supply near the surface. In one test, burning oil fuel over an area of 1,400 square feet was extinguished in three minutes, with 80 square feet of overhead natural ventilation. Steam was supplied at the rate of 1,800 pounds per hour. On another occasion, the fire appeared to be out, but was re-ignited when a 14 inch diameter viewing port near the surface was opened.

Fig. 9 shews diagrammatically an arrangement of steam smothering as fitted to H.M. Ships, with a system for introducing steam through flexible hoses into compartments adjacent to machinery spaces.

(*d*) **Carbon Dioxide.**

Fixed installations employing CO_2 are used in industry, in cargo vessels, and for giving protection to machinery spaces of some diesel driven naval vessels. They are suitable for inflammable liquids in tanks having only a limited surface area, enamelling ovens, driers, electrical equipment, industrial processes, cinema projectors, and in ships' cargo holds, etc. Operation may be manual or automatic. A typical automatic release incorporates fusible links connected by a phosphor bronze cord to the operating gear at the gas cylinders.

CO_2 is stored as a liquid in drawn steel cylinders containing 50 to 80 pounds at 850 p.s.i. Cylinders may be fitted singly or in batteries with manifolds. In the Pyrene system, they are sealed by screw down closure valves with suitable wrenches stowed nearby. Batteries are arranged to discharge in groups of four, valve outlets being connected by means of copper loops to a common $\frac{3}{4}$ inch CO_2 manifold which is led to a control box in which are fitted the distributing valves releasing the gas to the affected cargo space. One distributing valve is provided for each space. When CO_2 is used for the protection of machinery spaces, piercer type cylinder valves are used instead of screw down valves, and the full number of cylinders necessary for the space concerned are released simultaneously, in order to give a complete discharge in about one minute.

A smoke detecting device is usually fitted in merchant vessels in association with the CO_2 extinguishing system. It may incorporate a photo-electric cell for the operation of a warning signal. Or more simply, consist of a cabinet connected by galvanised piping to each hold, with an exhauster continuously drawing up samples of air which are passed into the wheelhouse. Visual indication is a M.O.T. requirement. As smoke is evolved before any serious temperature rise takes place, its presence in the wheelhouse gives ample warning. Upon operation of the release

mechanism, the gas is passed into the affected hold through the same piping as is used for sampling the air.

In the "Pyrene" combined smoke detecting and extinguishing installation (shewn diagrammatically in Fig. 10), the control box is generally fitted on the deck below the smoke cabinet. The distributing valves are all normally open between cargo spaces and the cabinet. They are only opened to the CO_2 when smoke has been detected. The special 2-way valve used for these combined units makes it impossible for CO_2 to pass to the detector cabinet. All distributing pipes, pipe fittings and valves are tested to M.O.T. requirements.

Messrs. Walter Kiddie, who may be regarded as pioneers of CO_2 smothering in ships, have introduced a system which cuts down installation costs to some extent, in which a single pipe is taken from the cabinet, situated in the cylinder room, to an audible detector, with visual indication, in the wheelhouse. Upon detection, it is necessary to proceed to the cabinet, where the space affected can be identified and the release mechanism operated. The layout in general is in other respects similar to that indicated in Fig. 10.

It is understood that CO_2 systems are fitted in a large proportion of modern tankers for dealing with fires in the machinery spaces, as against steam installation in older vessels of this type.

The 1952 Fire Appliances Rules require the equipment to be capable of providing a minimum of free gas equal to 30% of the gross volume of the largest hold in the ship, on a basis of 9 cubic feet per pound of liquid CO_2.

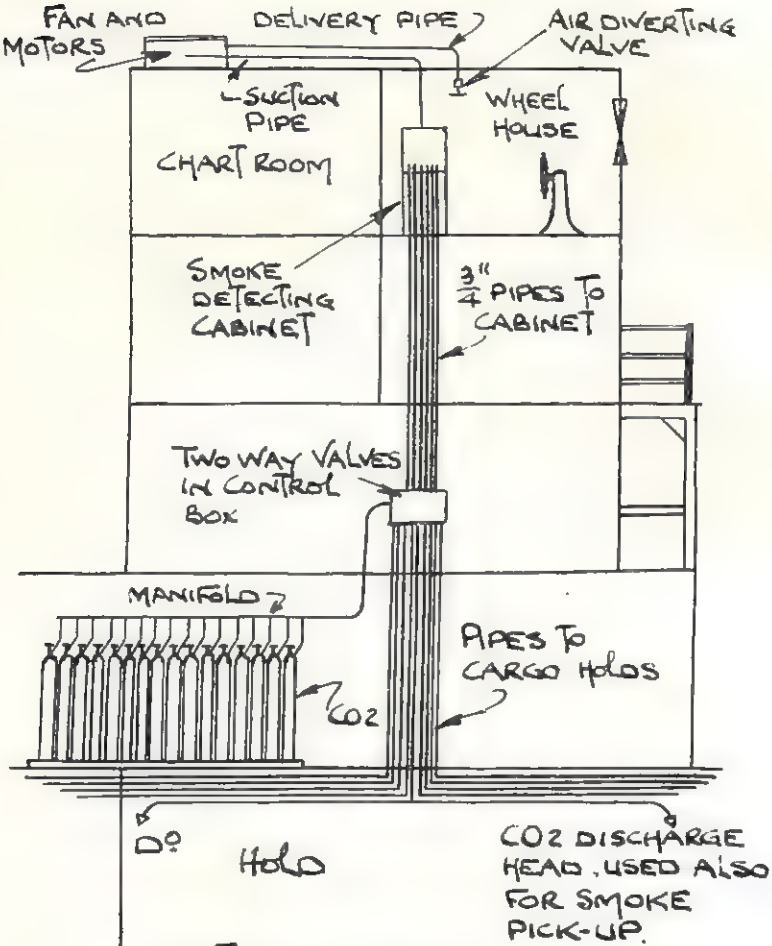
Sometimes the gas piping system is connected with the steam distribution box in the engine room, so that steam may be used alternatively if desired.

Where CO_2 protection is fitted to machinery spaces, it might be advisable to fit exhaust ventilation low down to clear the gas in the event of an accidental discharge. The 1952 Rules require that means must be provided whereby audible warning is given prior to the release of CO_2 into any working space.

A most interesting example of an automatic CO_2 installation is that fitted to cinema projectors using inflammable film. This not only extinguishes the fire, which almost invariable occurs in the "gate" if it occurs at all, but cuts off the arc and stops the motor. It is practically instantaneous in operation.

(*e*) **Methyl Bromide.**

The application of installations employing this medium is limited because methyl bromide is expensive, its vapours are highly toxic, and it has a corrosive effect on some metals, particularly aluminium and its alloys. It may be used for the protection of enclosed spaces and inflammable materials in a similar way to



SECTION SHOWING COMBINED SMOKE DETECTION AND CO2 FIRE EXTINGUISHING INSTALLATION. DIAGRAMMATIC ONLY.

Fig. 10.

CO_2, but in general it is restricted to aircraft power units, and in naval service to petrol driven coastal craft and landing craft, which constitute the greatest fire risk of all war vessels.

In naval craft, the system is operated from either the bridge or the engine room. The installation has an equipment weight one tenth that of CO_2. This is because methyl bromide requires to be pressurised only to 50 p.s.i., whereas cylinders of CO_2 are charged to over 800 p.s.i. A cylinder containing 24 pounds of methyl bromide will release nearly 90 cubic feet of gas, which is $3\frac{1}{3}$ times as heavy as air. The gas has no odour and to ensure adequate warning in the event of a slow leakage, supplies of the liquid to the Navy contain a lachrymatory agent. Efforts are being directed towards the use of a suitable substitute, which should possess as good an inhibitory factor but be much less toxic.

(*f*) **Foam Installations.**

The nature of foam and the methods of application are discussed elsewhere. Fixed foam systems cover oil fire risks ashore and in ships. Almost all tank farms are fitted for the introduction of either chemical or mechanical foam by means of pourers. Many tanks are also fitted with means of injecting foam into the base, whence it bubbles through to the surface. When the hazard to be protected is confined in an enclosed space, piping and pourers are so sited that a foam blanket can be poured over the entire floor area. This would be necessary with oil filled electrical equipment such as an indoor transformer.

Installations of the foam type are used ashore principally to protect oil storage tanks ; open dip tanks of inflammable liquids used in industrial processes ; spaces where inflammable liquids may run over the floor ; electrical apparatus and enamelling ovens, etc.

Automatic operation can be arranged but tends, in a mains-operated installation, to be more complicated than in systems employing other media. This arises largely out of the necessity to incorporate a device for shutting off the water supply as soon as the foam compound is exhausted, as, unless this was arranged, the foam blanket would tend to wash away and the addition of water to the fire might lead to a very serious spread. In a self-contained pressurised system, the supply of foam compound can be arranged to outlast the gas.

In **merchant ships,** fixed foam installations may be fitted to protect machinery spaces, using either chemical or mechanical foam. The latter system is said to involve less maintenance.

In the case of mechanical foam, the installation is operated either off the ship's main or from tanks which can be pressurised with a gas such as CO_2. The 1952 Fire Appliances Rules require

an equipment capable of producing a 6 inch blanket over the whole of the tank top, in oil fired ocean going vessels, and usual practice is to provide a capacity to effect this in about 6 minutes.

General practice is to discharge the foam underneath the floor plates, with additional discharges to such vulnerable spots as oil heaters and pumps. Foam spreaders are arranged on a liberal basis. Foam makers are fitted whose function is to convert the mixture into foam by aeration. These are arranged above floor plates, each feeding 2 or 3 spreaders.

Fig. 11 shews a Pyrene foam installation operated off the fire-main. Foam compound is stored in a steel tank and is drawn into the water stream by means of an inductor. The correct mixture of water and compound is delivered to the foam makers. A pump delivery pressure of about 75 p.s.i. is required.

Fig. 12 shews a Pyrene self-contained system operating from pressurised tanks of water. The water and compound tanks are designed to working pressures of 100 p.s.i. and tested to 175 p.s.i. The pressurising CO_2 is stored in liquid form at 800-900 p.s.i. Its flow is controlled by an orifice plate at the entry of the water tank, to maintain the working pressure of 100 p.s.i. A safety valve is fitted to blow at 105 p.s.i.

In either system, pipe sizes are usually arranged so that the velocity of the water or mixture does not exceed 10 feet per second, giving a friction loss of about 1 foot head in 10 feet which normally is not excessive in the lengths of piping involved.

Chemical foam installations were generally of the two solution type, followed later by dry chemical systems working off the firemain. The solutions system operated by gravity, which necessitated the chemical tanks being sited high up, usually on the boat deck. The acid and alkali valves were geared together. The two solutions were brought together either at one central point in the boiler room, or sometimes at a number of points in the distribution room. The capacity of the solution tanks was based on 6″ of foam over the area to be protected, with an expansion of 8 from the combined solutions. The 1952 Fire Appliances Rules includes a schedule of requirements for foam installations.

Fixed foam installations are not fitted in *warships* owing to their vulnerability to action damage. Instead, a number of watertight tubes, into which foam branch pipes may be inserted, are arranged in the crown of each main machinery compartments, so that foam can be discharged on to a suitable bulkhead and thence flow to the bilge. Tests carried out at Haslar showed this method to be highly effective, an oil fuel fire involving a liquid surface of 1400 square feet being extinguished in 5 minutes by foam admitted through four tubes, one in each corner of the compartment.

MECHANICAL FOAM INSTALLATION OPERATED FROM FIREMAIN

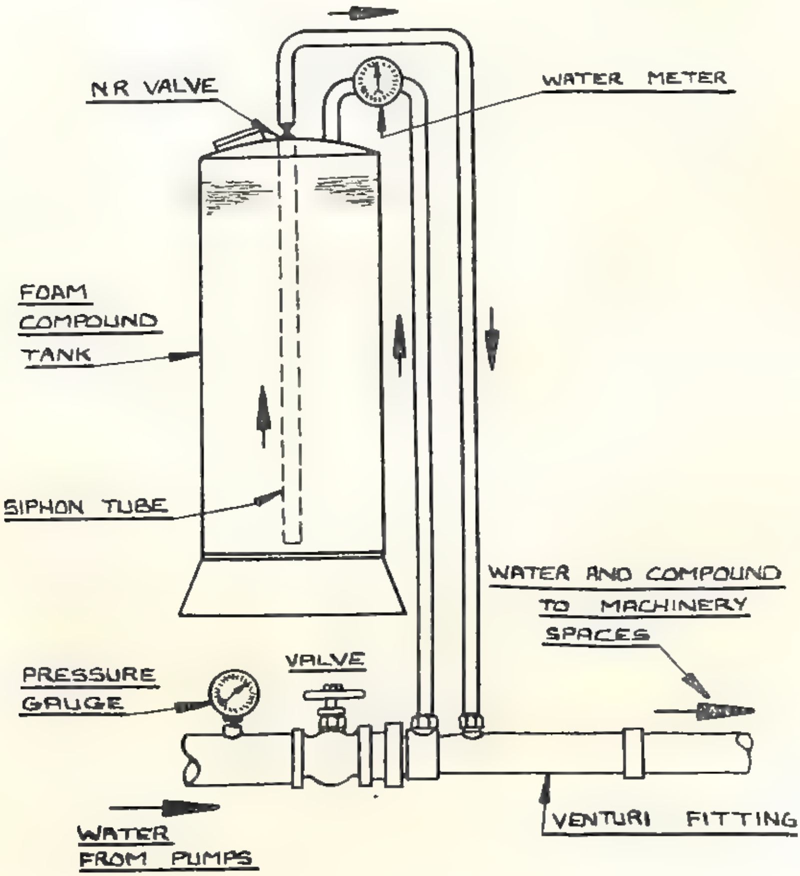


Fig. 11.

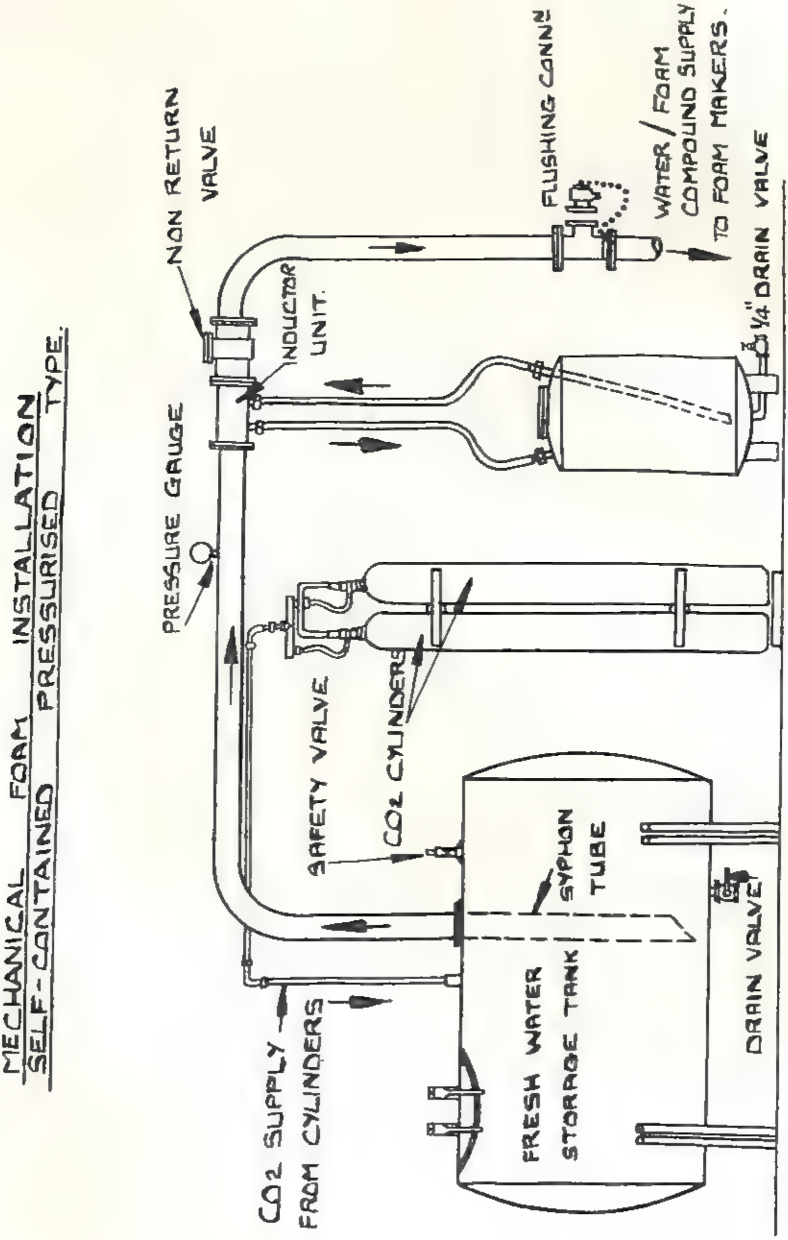

MECHANICAL FOAM INSTALLATION
SELF-CONTAINED PRESSURISED TYPE.
NON RETURN VALVE
FLUSHING CONNN
WATER / FOAM COMPOUND SUPPLY TO FOAM MAKERS.
INDUCTOR UNIT.
1/4" DRAIN VALVE
PRESSURE GAUGE
SAFETY VALVE
CO_2 CYLINDERS
SYPHON TUBE
FRESH WATER STORAGE TANK
DRAIN VALVE
CO_2 SUPPLY FROM CYLINDERS

Fig. 12.

Foam Fire Engines.

Under certain circumstances the 1952 Fire Appliances Rules require an approved foam type extinguisher, of at least 30 gallons capacity, to be sited in the boiler room, with sufficient length of hose to reach any part of the compartment. This appliance is an enlarged form of the 2 gallon chemical first-aid extinguisher, and is usually referred to as a foam fire engine. It is mounted on trunnions in gunmetal bearings, upon a frame of substantial construction which is bolted to the floor plates. When it is required to be operated, the top valve is unscrewed, the locking pin removed from the bearing, and the apparatus turned over in the trunnions. Foam is made in precisely the same way as with the 2 gallon extinguisher. A 10 gallon foam extinguisher operates in a similar manner.

(g) **Inert Gas for Fire Prevention.**

The systems described previously are installed for extinguishing fires. The principal function of an inert gas for fire prevention is to obviate the formation of explosive mixtures of vapour or dusts in enclosed spaces. Certain commercial processes are so dangerous that they are not practicable unless protected by an inert atmosphere. This type of protection is applicable to enclosed machinery and to storage of liquids, as for example, the use of boiler exhaust gas to protect the tanks of oil tankers. It may be used to purge tanks prior to repair ; for drying ovens and reaction equipment ; for the elimination of dust hazards involving grain, starch, coal, sugar, etc. ; to protect grinders, mixers, pulverisers, dust collectors, sacking machines, etc., which also have a dust hazard ; and to protect operations carried out at temperatures above the ignition point of the material.

Any inert gas may be used for protective purposes, but practical considerations limit large scale use mainly to carbon dioxide, nitrogen, and exhaust gas of internal combustion engines.

(2) **Fixed Automatic Fire Detecting and Alarm Systems.**

These systems are primarily fitted in buildings which have no fixed extinguishing installation. Where extinguishing systems are fitted, they usually incorporate an alarm device. Under certain circumstances, automatic detecting and alarm systems are a requirement in passenger ships. M.O.T. approval of the type to be fitted will be necessary.

Generally speaking, fire detecting devices are of three classes :—

- (*a*) those which operate at a fixed predetermined temperature
- (*b*) those which function when the rate of rise of temperature exceeds a predetermined value
- (*c*) smoke detectors.

Rate of rise types are stated to be more sensitive than those operating at fixed temperatures, and are used particularly where very prompt operation is required. Normally, however, fixed temperature devices are sufficiently rapid.

Thermostatic devices operating at a fixed temperature are widely used. They may employ bi-metal strips, the expansion pressure when heated of a liquid in a copper tube, a fusible link separating two conductors, or other similar mechanism. In these types, the effect of heat on the operating part is to close the contacts thus causing a relay to function which conveys an alarm, either to a fire station or other selected position.

Rate of rise detectors may be based on an electrical out-of-balance condition between two conductors, energised either from the mains or from a battery with a trickle charger. The effect of heat is to increase resistance and the resulting change of current operates a relay.

Smoke detectors are fitted to the cargo holds of merchant ships, the M.O.T. not permitting the use of any device in these spaces involving electrical power. It is claimed for them that they will give an alarm before dangerous temperature conditions are set up, and in any case before the appearance of flame. They usually incorporate a photo-electric cell, interruption of the light beam causing make or break in an electric contact. Air from the protected space is drawn up to the detector by an exhaust fan which must run continuously. In many cargo vessels, detection is visual and by smell, the photo-electric cell equipment not being fitted. Discharge of the samples of air is led into the wheelhouse. Audible warning, usually by means of a photo-electric device, is an additional feature, valuable in port when the bridge is not manned.

In general, automatic detection systems can be made to operate relay switches for bells, sirens, extinguishing systems, stopping of motors and fans, and closing of fire doors, etc.

---

9. WATER SUPPLIES.

An efficient water supply is obviously essential to the success of all major fire fighting operations.

Ashore.

Supply ashore is arranged by means of a network of water mains with which large towns and many rural areas are provided, although it must be borne in mind that the system is laid on primarily for domestic purposes, and not for fire extinction. In some towns there is a network of hydraulic mains, carrying water under pressures

which may be anything between 700 to 1100 p.s.i. for the operation of cranes, lifts, etc. Buildings which are linked up with this supply are fitted with injector hydrants.

Supply through the mains is maintained by pumping or gravitation or a combination of both. The fireman has access to the water by means of hydrants, each fitted with a valve and outlet, to which he attaches his standpipe or hose.

Hydrants began to replace fire plugs about 1830, and since their introduction, over 50 varieties have been installed by various local authorities, none of the fittings being interchangeable. The disadvantages of this arrangement are obvious. Steps are now being taken to standardise underground hydrants throughout the country, to sluice valve or screw down valve type, with round thread outlets, conforming to B.S.S. 750/50.

Merchant Ships.

Simplicity is the keynote of the arrangements for the supply of water for fire fighting. Usually both the ballast pump and the general service pump can discharge into the firemain, but the former is normally of rather low head. The same applies to a Downton pump which may also be arranged to discharge into the firemain. The Downton pump is hand operated, requiring 2 to 4 men, and capacity varies between about 460 to 1500 gallons per hour (2 to 7½ tons per hour) according to the size of the pump. Pressure depends upon the number of men operating it but would not normally be more than about 30 p.s.i. The firemain is tested to from 150-250 p.s.i. as a maximum, which indicates working pressures from about 75 p.s.i. when the system is new. Experience during the war with vessels taken up for naval purposes was that both pump capacity and pressure were generally too low.

In other than small ships, the firemain is usually a galvanised iron pipe 2 inches to 4 inches diameter, led fore and aft along the gutter or bulwark. Firemain lines may, however, be taken from the pump and led under the deck overhead. A number of hose connections with screw down valves are fitted at various points, including machinery spaces. Branches are taken off the firemain to serve the various 'tween deck spaces.

Pump requirements are discussed elsewhere.

H.M. Ships.

In naval vessels the firemain (or main service) generally runs throughout the ship, either as a single pipe, or as cross connected lines running port and starboard in the form of a loop. It varies from 3 inches diameter in destroyers, to 6 inches in large ships.

Supply is from fire and bilge pumps in the machinery spaces, and hull and fire pumps outside them. The number of pumps may vary from 3 in an old destroyer, with a total capacity of 80

tons per hour, to 24 in a carrier, providing some 2000 tons per hour. The tendency generally is towards increasing pumping capacity. In assessing pump capacities, "action" requirements of cooling water, sanitary services, etc., should be considered, the aim being a margin of 30 to 40 tons an hour to supply two branch pipes for fire fighting.

The normal working pressure in the firemain is 75 p.s.i. To enable any pump to run continously without overheating, for maintenance of adequate pressure at all times, "leak off" arrangements are fitted, giving a constant flow of 4 to 5 gallons per minute while the pump is running.

Fire hydrants are sited so that water from at least two 40 feet hoses can be directed on to a fire in any compartment. Hydrants are fitted in main and auxiliary machinery spaces.

Isolation valves are fitted at each main watertight bulkhead to prevent flooding in the event of damage. They are also fitted on each side of each riser from the pumps, and one on either side of each branch serving a magazine spraying system. Pressure gauges are also fitted on the firemain at the junction of the pump risers, and in other selected positions, to indicate damage.

Portable fire pumps are usually supplied to naval vessels to ensure a water supply in the event of loss of power. The two-man manual pump, a double acting reciprocating type, for destroyers and smaller vessels, will deliver about 11 gallons per minute at 30 p.s.i., sufficient for a $\frac{1}{4}$ inch nozzle or a foam branch pipe FBO. Suction is by hose direct from the sea.

Larger vessels are supplied with diesel transportable fire pumps. Each unit consists of a 12 H.P. horizontally opposed twin-cylinder diesel engine, directly coupled to a centrifugal pump having an output of 27 tons per hour at 50 p.s.i., with a maximum suction lift of 24 feet. Sea suction is provided by means of internal standpipes led from seacocks sited forward and aft. The unit weighs 580 pounds, and its dimensions are such that it will pass through a normal hatch or doorway. The pump is primed by means of an air pump operated by friction drive off the flywheel.

---

10. PRINCIPAL APPLIANCES AND HOSE COUPLINGS.

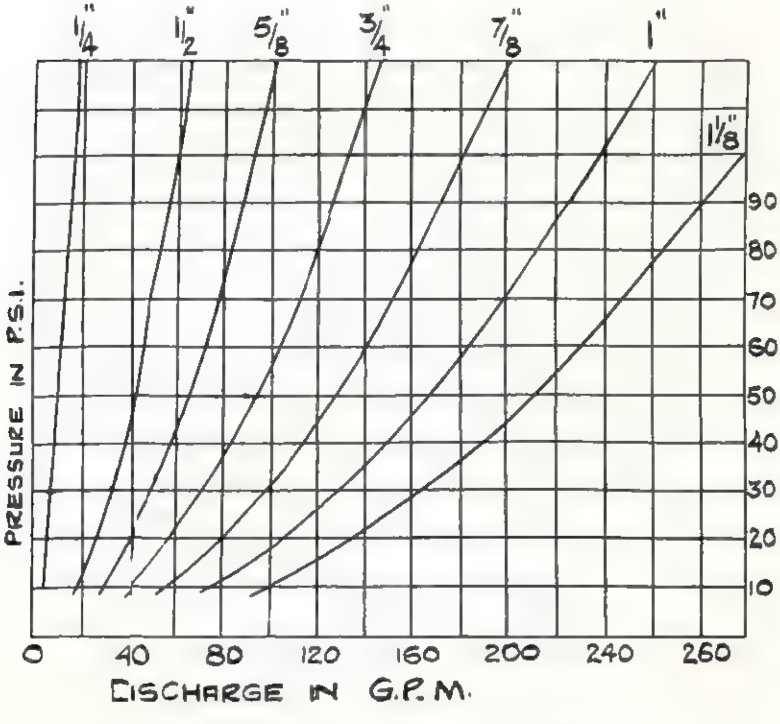
Ashore.

Principal appliances include hoses, nozzles, mobile pumps, escape gear, adaptors, foam branch pipes, etc., and are discussed in detail in the Manual of Firemanship, Volumes 1 to 3.

Large diameter nozzles in association with high pressure pumps are used for reaching the upper storeys in lofty buildings. This involves a large water consumption. Nozzles are necessary to

increase velocity and to give a good jet. They are made in a range of sizes from $\frac{3}{16}''$ to 2″ or even larger. Fig. 13 shows the water capacities at various pressures for a range of nozzles.

Foam and foam making branches used ashore and afloat are discussed separately, in view of the importance of this aspect of fire protection.



WATER CAPACITIES OF NOZZLES

Fig. 13.

In Merchant Ships.

In ships it is seldom necessary to project water great distances, and considerations of stability and pumping capacity make it essential to use the minimum to maximum effect.

Appliances working off the firemain in most merchant ships consist of plain nozzles, with spray nozzles in the machinery spaces of certain oil fired vessels. Canvas delivery hose is normally used and a length is often kept, together with a nozzle, in a glass fronted box built around the hydrant.

In H.M. Ships, canvas delivery hoses are used in association with jet/spray and fixed-spray nozzles. A length of hose to which is attached a jet/spray nozzle, is kept coupled up to each fire hydrant. The hose is flaked so that a firefighter has merely to run it out whilst an attendant prepares to open the valve. Valves are of the screw down type and are soft seated to ensure tightness on closing.

The jet/spray or diffuser nozzle is of great value in ship fire fighting. The water can be shut off by rotating the sleeve on the nozzle, without producing any appreciable hammer in the hose. Using spray, it is suitable for cooling bulkheads, for oil fuel fires provided the whole surface is exposed, for personnel protection, and for fires involving live electrical circuits up to 500 volts.

During tests at the Admiralty Fire Test Ground at Haslar, an oil fuel fire covering 300 square feet under the floor plates of an engine room mock-up, was extinguished in a very short time, with one diffuser nozzle using spray. This type of nozzle is shown in Fig. 14.

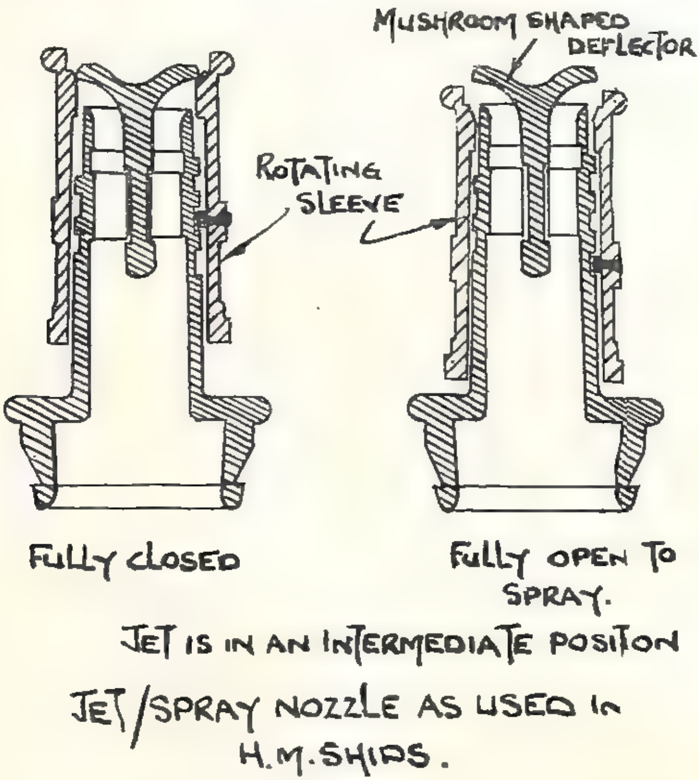


Fig. 14.

To avoid the possibility, under conditions of darkness or smoke, of using a jet of water on an oil fire, a proprietary nozzle capable of producing spray only, is stowed in positions where the chief risk is from oil fuel. The standard size of canvas delivery hose is $2\frac{3}{4}''$. A smaller size is used below decks where space is restricted. Being permeable, canvas hoses are resistant to external heat, but they are susceptible to abrasion, and deteriorate very rapidly if given hard use on rough surfaces. At present there is a trend towards the use of a rubber lined hose, a good type being one with a nylon weft and cotton warp. The weft runs circumferentially and provides resistance to bursting.

Hose Couplings.

The standard delivery hose coupling used in the Fire Service is the $2\frac{1}{2}''$ instantaneous type, to British Standard Specification No. 336.

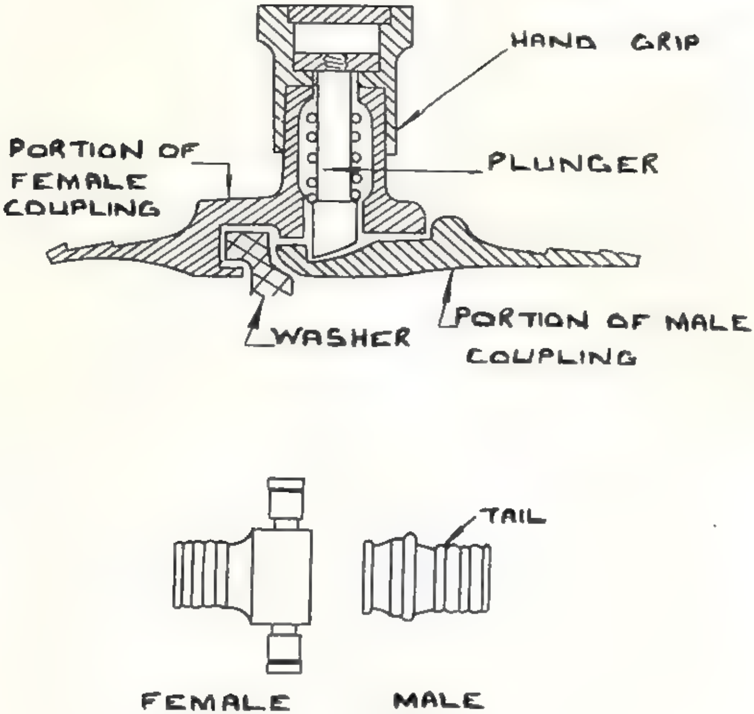
This coupling was adopted for naval vessels for delivery hoses and fire hydrants, in 1942, replacing the symmetric coupling known as the Admiralty Standard Bayonet Joint.

The instantaneous coupling is an interlocking type with male and female halves. Hydrants have a screw down valve with a female coupling, either cast on or bolted to a flange. The female coupling on the hose is taken to the fire. With a system using this type of coupling, it is important to remember that all outlets are female. Nozzles and branchpipes will therefore have a male coupling at the inlet end to connect to the hose. Dimensions of mating parts and other essential particulars are laid down in B.S. 336.

To connect, the male is forced into the female half until the lip of the former presses back the two plungers in the horns on the female half, and forces them behind the rim on the male. The method of operation can be seen from Fig. 15. Water pressure on a specially shaped rubber washer ensures watertightness. The couplings are released by pulling apart the caps on the horns, this action withdrawing the plungers against the compression of springs.

Hydrant couplings are usually fitted with a type of pressure release, with a single plunger, instead of one in each of two horns as in the coupling shown in Fig. 15. The plunger is operated by a twist action working on a cam mechanism. Such a fitting permits couplings being parted under internal pressure. The normal instantaneous hose fittings cannot readily be separated under anything greater than a head of a few feet of water.

Instantaneous couplings have proved very successful in practice. The couplings themselves, *i.e.*, the mating portions, have standardised dimensions, but the tails vary to suit different size hoses, as shown in Fig. 16, which for convenience illustrates male halves only.



2½" INSTANTANEOUS COUPLING
Fig. 15.

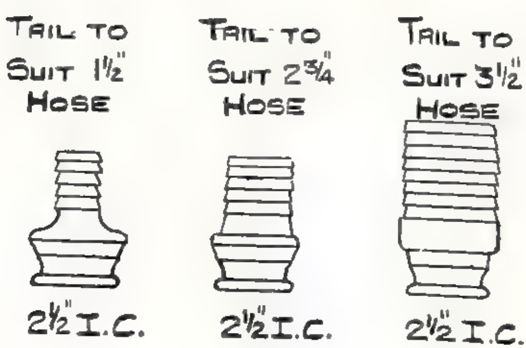


Fig. 16.

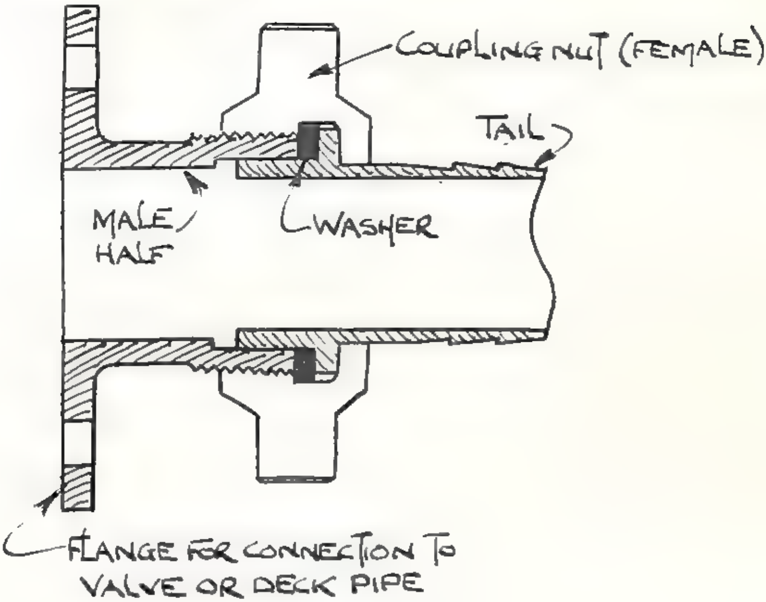
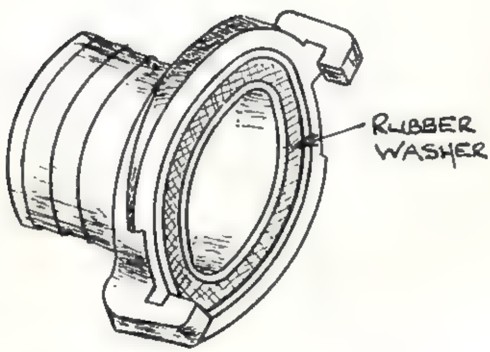


Fig. 17.



SYMMETRIC HOSE COUPLING
A.S.B.J. OR NUNAN & STOVE

Fig. 18.

Some merchant ships are fitted with instantaneous couplings, but generally there is considerable variation in types fitted to firemain outlets. The most widespread is the screw coupling with a Whitworth thread, 6 or 7 t.p.i., as shown in Fig. 17. In all systems using screw connections, outlets are male.

Other vessels have the Nunan and Stove interlocking type, similar to the A.S.B.J. This is a symmetric fitting, both parts of the coupling being identical. It is illustrated in Fig. 18. Connection is made by twisting the face of one half into the face of the other, a tight connection being made by wedge-shaped flanges on each part. The Nunan and Stove coupling is extremely convenient, as it is immaterial which end of the hose is taken to the hydrant. It is, however, apt to work loose under some circumstances, since there is no positive closure. Couplings are of various sizes to suit different size hoses. The most general is the 2½ inch.

There is clearly plenty of scope for standardisation of hose couplings used in commercial vessels. The Working Party on Fire Prevention and Fire Fighting in Ships in Port, whose report was published by H.M. Stationery Office in 1950, recommended that in new ships all hose couplings and outlets on the firemain to which hose connections are made, should be of the 2½ inch instantaneous type to B.S. 336.

Information relating to foreign ships is very sparse. Some small French vessels, chiefly trawlers, have 2½″ I.C.'s, but in general, screw types may be expected. Both Germany and France have standardised to a great extent on symmetric couplings. The German is the Storz, usually in aluminium. Watertightness depends on water pressure acting on a rubber cushioning. It has locking lugs mounted on a movable countersunk ring on each half coupling. The French type is the D.S.P., which is provided with fixed locking jaws. Connection is positive and watertightness is independent of internal pressure. It is believed that many merchant vessels of these countries are fitted with the Storz or D.S.P. type of hose coupling, as the case may be.

The great diversity of types of fire hose couplings amongst ships of all nations, was brought to the attention of the International Conference on Safety of Life at Sea, 1948, which in its report has recommended that endeavours should be made towards an international standardisation.

11. FOAM AND FOAM APPLIANCES.

Foam is the most effective medium in general use for dealing with fires involving inflammable liquids such as oil fuel, diesel oil or petrol. In particular instances, other media are used with success. For instance, high pressure water spray will extinguish oil-fires provided the entire surface area can be covered. This

is a condition not always readily satisfied in, say, the machinery spaces or the bilges of a ship. It can, however, be met in certain shore installations, and an extinguishing system employing such a spray is discussed elsewhere. Steam or an inert gas may also be used, but here again it is essential that there should be no air supply near the burning surface, and there is always the danger of re-ignition when the concentration of smothering vapour has been dissipated.

Foam acts to some extent as a coolant by virtue of its water content, but its most useful function is to interpose a heat resistant layer between the fuel surface and the heat of the flames, which burn, not at the surface where the concentration is too rich, but a little distance from it. On low flash point fuels, the cooling effect is of less value, since such fuels will continue to evolve inflammable vapours at temperatures below normal. It will, however, tend to slow down the rate of emission of the vapours.

The possibilities of foam as an extinguishing agent were demonstrated by Professor Laurent at St. Petersburg in 1904. In 1912 the first foam apparatus was introduced in England for Fire Brigade use. It consisted of generators employing chemical solutions. Since 1912 the use of foam has become widespread, development of techniques and of equipment generally being greatly accelerated during the last war.

Foam may be generated

(*a*) by chemical reaction.

This is called chemical foam. It is produced by bringing a solution of sodium bicarbonate into contact with a solution of aluminium sulphate, in the presence of a stabiliser, which may be saponin, liquorice, soap, or glue, etc. A reaction takes place, as a result of which a mass of bubbles is formed, filled with carbon dioxide. The stabiliser takes no part in the reaction, but strengthens the walls of the bubbles, and prevents them from bursting under heat conditions.

Large fixed installations may employ the chemicals either in powder or solution form. In some systems, the two chemicals in powder form are premixed, a satisfactory arrangement provided the mixture is kept dry, since no reaction occurs until water is added.

(*b*) by mechanical agitation of a foam compound with air and water, producing mechanical foam.

Foam compound is an aqueous solution, usually of a protein compound containing hoof and horn, or hydrolised blood. It is neutral in reaction and generally non-corrosive.

> The agitation may be accomplished by a positive action rotary pump which induces water, foam compound, and air, and delivers foam, as in some Crash Tenders used on airfields. Or it may be performed by a foam making branchpipe, which is the apparatus in general use in naval vessels, or by some other form of mechanical foam generator. In these types of appliances, foam compound is introduced into the water stream by means of an atmospheric venturi, which in a foam branchpipe is incorporated in the waterhead, or which may be a separate piece of equipment, as in the inline-inductor. In each case the principle is the same. A point of low pressure in the waterstream is created by converting pressure head to velocity head. A short length of suction hose from this point leads to a container of foam compound, and the compound is forced through the tube by atmospheric pressure.

Foam branchpipes are supplied to the Royal Navy and to some merchant vessels, for dealing with oil fires. Those supplied to the navy differ from shore appliances only in so far as the methods of foam compound injection is concerned. In naval vessels, a suction pick-up assembly is used in the larger branchpipes, as shown in the sketch in Fig. 19. The suction pick-up assembly is simple to operate and requires little maintenance. It involves very little pressure loss. The end of the foam compound suction hose has fitted to it a combined drum piercer and strainer, which must be thrust through the top of the drum of compound.

Shore appliances above the size of that illustrated use either the inline inductor or the multiple jet inductor. The disadvantage associated with the inline inductor is the 25% pressure loss across it, which prohibits its use in warships where such a loss cannot be afforded, having regard to the reduced firemain pressure which might obtain under damage conditions. Smaller branchpipes in the navy and elsewhere usually draw foam compound by means of the usual inductor from a knapsack tank carried on the operator's back.

Very briefly, a typical foam branchpipe consists of a hose coupling brazed to a waterhead casting, usually all in gunmetal or brass, the casting being secured to a conical mixing chamber reducing to a cylindrical discharge tube. The whole may be over 6 feet long for the largest type used in ships. The waterhead has 4 nozzles through which the water must pass. The centre nozzle incorporates an inductor, and its outlet is designed as a diffuser. The 3 outer nozzles are set obliquely so that the water issues from them in conical form. Foam compound is induced into the stream at the inductor, and water plus foam compound mixes with the water issuing from the outer nozzles, the whole being violently

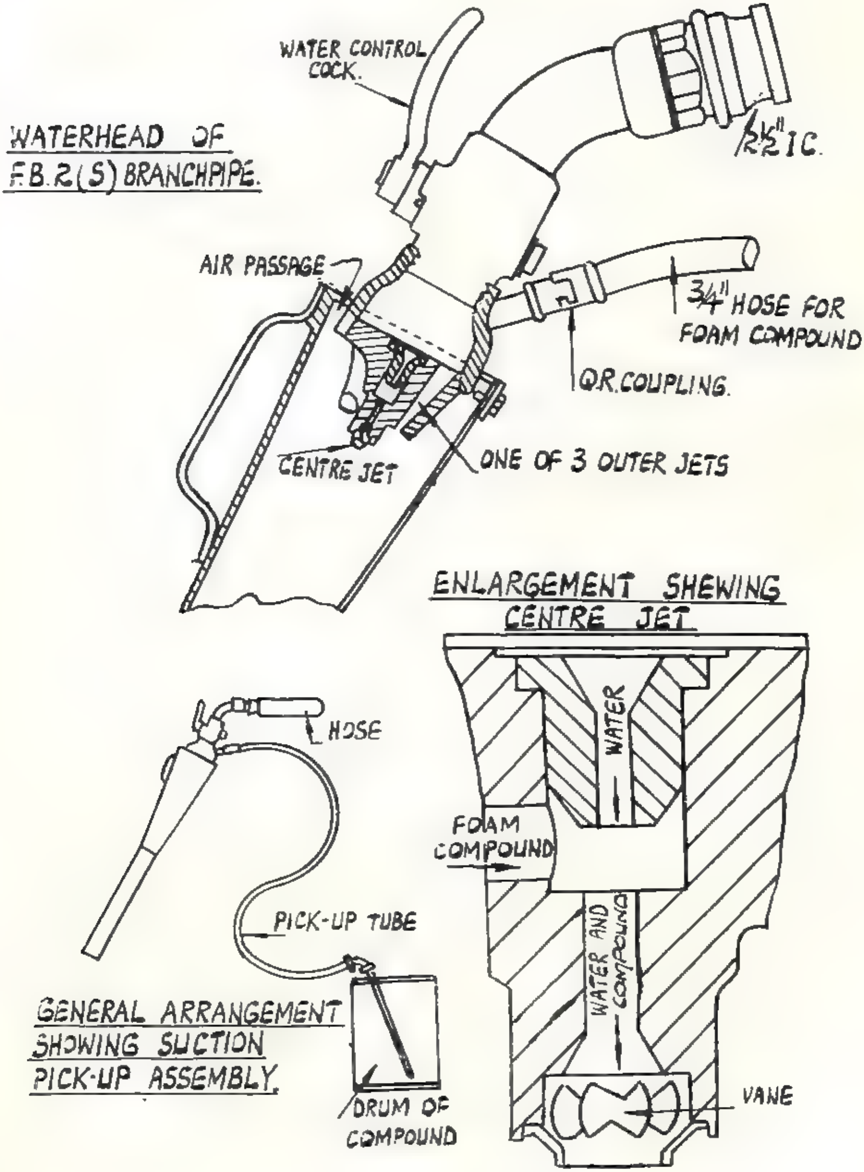

WATER CONTROL COCK.
2½" R.I.C.
WATERHEAD OF F.B.2(S) BRANCHPIPE.
AIR PASSAGE
3/4" HOSE FOR FOAM COMPOUND
Q.R. COUPLING.
CENTRE JET
ONE OF 3 OUTER JETS
ENLARGEMENT SHEWING CENTRE JET
HOSE
WATER
FOAM COMPOUND
PICK-UP TUBE
WATER AND COMPOUND
GENERAL ARRANGEMENT SHOWING SUCTION PICK-UP ASSEMBLY.
VANE
DRUM OF COMPOUND

Fig. 19.

agitated in the mixing space to form a spray which moves with considerable velocity up the discharge tube. This produces a piston-like effect, which draws air in through an annular space between the waterhead and the casing of the mixing chamber. The air mixes with the spray of water and foam compound, and the violent aeration produces foam consisting of air-filled bubbles.

Fig. 19 shows the waterhead of a branchpipe designed specially to produce a sloppy foam for easy flowing in bilges. It has a goose neck attachment, peculiar to this type, to avoid hose kinking when the branchpipe is thrust into a foam inlet tube for the admission of foam to machinery spaces, as fitted in naval vessels.

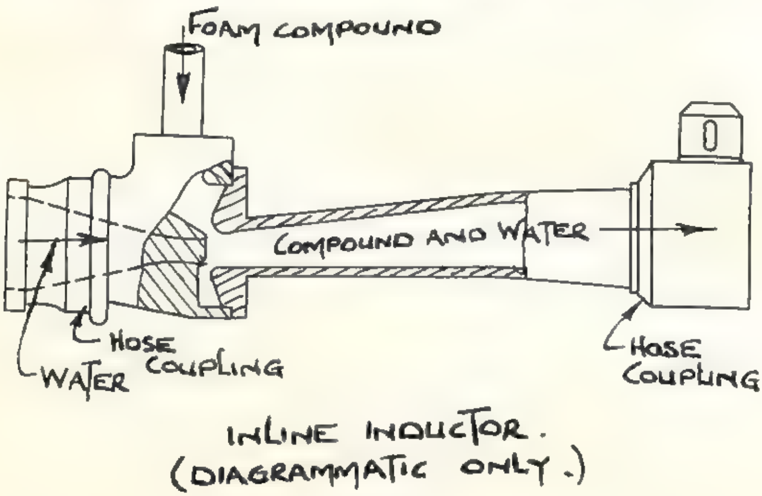


Fig. 20.

Fig. 20 illustrates the inline inductor, which is specially shaped to convert pressure energy into velocity energy, with a consequent drop in pressure at the point of maximum velocity to something below atmospheric. The foam compound enters circumferentially at this point, and is carried forward in the water stream into the expanding outlet, where velocity is reduced, and about 75% of the pressure recovered. The balance is expended in doing work on the compound and in friction. The inline inductor does not aerate. This process is carried out at the branchpipe.

The multiple jet and other types of inductor, as used in the Fire Service, are discussed in some detail in Volume I. of the Manual of Firemanship.

Mechanical foam as produced by a branchpipe usually consists of approximately 12% water and 88% air. The usual expansion

figure is about 8, *i.e.*, 100 g.p.m. of water with a 3% concentration of foam compound gives about 800 g.p.m. of foam. It is a bad conductor of heat, as may be inferred from its structure. After a fire on which it is used, the temperature of the upper layer will not be much above that of the atmosphere. A good foam blanket will remain effective for some time after application, and this obviates the danger of re-ignition.

For some years mechanical foam was regarded with suspicion because of its air content, which critics said would tend to sustain a fire. But it was demonstrated eventually that the flames are subdued by the structure, extinction not depending on the contents of the bubbles. In fact, an American publication states that in 1931 tests were carried out using foam filled with oxygen, which functioned quite satisfactorily as an extinguishing agent.

The table below gives approximate figures of water capacity, foam production, etc., for various size branchpipes :—

Type	User	Method of Use	Consumption g.p.m. Foam Compound	Consumption g.p.m. Water	Foam produced g.p.m.
F.B.O.	H.M. Ships. Fire service and shore fire-fighting generally.	In association with a manual pump supplied in the Navy to destroyers and smaller ships. Has knapsack tank equipment.	0·4	8·0 at about 35 p.s.i.	70
F.B.2 (P)	H.M. Ships	Has suction pick-up assembly.	2·0	44 at 50 p.s.i.	375
F.B.2 (S)	H.M. Ships.	For oil fires in machinery spaces. Has s.p.u. assembly.	2·3	65 at 50 p.s.i.	420
F.B.2	Merchant ships Fire Service and shore fire-fighting generally.	Has knapsack tank equipment.	1·75	50 at 100 p.s.i.	400
F.B.10 (P)	H.M. Ships.	For flight decks and hangars in aircraft carriers. Has s.p.u. assembly.	3·1	97 at 50 p.s.i.	800
F.B.10	Shore fire-fighting generally.	With inline inductor or multiple jet inductor.	3·0	100 at 100 p.s.i.	800
F.B.20	do.	Multiple jet inductor.	6·0	200 at 100 p.s.i.	1600
F.B.30	do.	do.	9·0	300 at 100 p.s.i.	2400

12. PORTABLE EXTINGUISHERS.

Portable extinguishers, called first-aid fire fighting equipment, are small hand appliances for dealing with fires in their incipient stage. They cannot be expected to extinguish a fire which has been allowed to develop. Speed of attack is therefore essential. This implies availability of the right type of appliance in good working order, and personnel sufficiently trained in its use to apply it. It is elementary knowledge that most fires if tackled at their inception could be dealt with by a hand extinguisher.

Types of Extinguishers.

Those mostly in use are as follows :—

(*a*) Water type (soda acid). Cylindrical or conical in shape, made of copper or steel. Contains a solution of sodium bicarbonate and a bottle of acid, usually sulphuric. A dilute solution of sodium sulphate and bicarbonate is expelled by the gas pressure generated by the chemical reaction between the acid and the alkali. Standard size is 2 gallons. B.S. 138/1948 deals with construction, materials and their thicknesses, performance, tests, etc.

(*b*) Water type (gas pressure). Similar in construction and appearance to the soda acid type. The expellant is compressed CO_2 contained in a separate charge whose sealing disc is pierced when the appliance is operated. The outer container is filled with water. This type is used in the navy, fitted with a short length of hose and a jet/spray nozzle. It is simple to operate and readily recharged. It is believed that this type of extinguisher is replacing the soda acid type for general use on railways. The standard size is 2 gallons. B.S. 1382/1948 deals with the construction, etc.

(*c*) Foam type. These are similar in construction and capacity to the water types. Foam is produced by chemical reaction between solutions of bicarbonate of soda and aluminium sulphate, and is discharged by the pressure generated in the reaction. The quantity produced is about 16 gallons. B.S. 740, Part I, 1948, covers construction, etc. Chemical foam extinguishers as used in H.M. Ships have a circular valve to each of the containers, the valves being coupled together. When the operator turns the handle at the top, both valves are opened. The appliance is operated in the inverted position. It has proved very effective.

(*d*) CO_2 extinguishers, containing liquid CO_2 at 800-900 p.s.i. The discharge device incorporates a horn and a high

pressure hose. The liquid, on release, expands about 450 times to gas.

CO_2 is clean, non-conducting, and non-toxic. It is, however, an asphyxiant, but symptons of distress give warning of its presence. It is $1\frac{1}{2}$ times heavier than air.

(*e*) Those employing vaporising liquids such as carbon tetrachloride (C.T.C.) or methyl bromide. Each of these is toxic, the latter especially so.

C.T.C. is closely related to chloroform and possesses similar anesthetising properties. It is an excellent solvent, and is well-known as a clothes cleaner. Its indiscriminate use for this purpose is, however, attended by great danger. The liquid is expelled as a jet or spray either by a hand pump, or by a charge of compressed gas, or by air pressure generated by an air pump. The vapour is $5\frac{1}{2}$ times heavier than air. It is decomposed by heat. The products of decomposition are more toxic than the natural vapour, and may include phosgene.

C.T.C. extinguishers should not be used in confined spaces. They are at present supplied to the Fleet for dealing with small fires in petrol engined equipment, and fires involving high potential electrical equipment. When used between decks breathing apparatus is necessary. B.S. 1721/1951 covers construction, etc.

Methyl bromide is a stable colourless liquid. Extinguishers employing it are pressurised with an inert gas (usually nitrogen) to 50-100 p.s.i. Toxicity of the vapour, which is odourless, is stated to be 10 times that of C.T.C. and for this reason, and in spite of its excellent extinguishing properties, it should not be used in buildings or confined spaces.

(*f*) Dry powder extinguishers. The powder is basically sodium bicarbonate, and in a current model is expelled by a compressed CO_2 charge. If used on small inflammable liquid fires there is the same danger of re-ignition as exists with all other extinguishing mediums except foam.

Applications. No one type of portable extinguisher is equally effective on all kinds of fires. The appliance should be selected to cover the particular hazard involved.

Briefly, water types should be chosen for carbonaceous combustibles where cooling is necessary, *e.g.*, wood, paper, textiles, etc.

Foam types are suitable for use on small fires involving inflammable liquids.

Generally speaking, with fires involving electrical equipment, CO_2 or C.T.C. is advisable if the circuit is live. If the current can

be switched off, water is the best medium, except if inflammable liquids are involved, when foam should be used. In H.M. ships the water type extinguisher supplied, which expels fresh water uncontaminated by chemicals, is safe to use, with jet or spray, on live electrical equipment up to 440 volts, 50 cycle A.C., and 800 volts D.C.

Siting of Extinguishers. No one should have far to go to reach the nearest appliance, which should be in a prominent and accessible position. B.S. Code of Practice, C.P. 402 : 401 Portable Extinguishers, which has a commercial application, makes recommendations as to distribution, suitability, inspection, maintenance, etc., stating that there should be one per 250 square yards, with not less than 2 per storey.

In **H.M. Ships,** portable extinguishers are sited to cover the hazard of galleys, oil-fired boilers, switchboards, radar and W/T., petrol compartments and petrol filling positions, cinema projectors and re-wind rooms, power boats, petrol engined equipment, etc. The appliance is stowed near the hazard, if possible immediately inside the entrance to the compartment concerned. In boiler rooms they are placed on the floor plates within easy reach of watchkeepers. Additionally, a proportion of foam and water types is sited at fire posts which form part of the damage control organisation, to deal with small action damage fires. Others of the water type are distributed throughout the ship in accommodation spaces, etc.

In the **Merchant Navy,** water-type extinguishers are used in passenger and crew spaces, the usual basis being two in each space on each deck with all watertight and fire doors closed. If passengers are accommodated in enclosed spaces above the upper deck, there is normally at least one on each side of the ship in such spaces. For machinery spaces foam types are a requirement, and CO_2 or C.T.C. are recommended by the M.O.T. for electrical fires. C.T.C. extinguishers are in fact used at switchboards and in W/T. rooms, in a large number of vessels, but the M.O.T. frowns on their application where the operator is in an enclosed space. For galley fires, CO_2 or foam types are used, the latter perhaps being more frequently found. Certainly for fires involving cooking fats or oils, a foam extinguisher would be more effective, as it reduces the possibility of re-ignition.

Portable extinguishers which contain water or an aqueous solution should not be sited in positions where they are exposed to temperatures lower than 40°F. Neither should anti-freeze compounds be added to their contents, since this might cause corrosion or interference with chemical reaction.

It should be noted that although the British Standards quoted above in respect to the various types of extinguishers, cover require-

ments for commercial practice generally, extinguishers for merchant vessels must conform in the first place to the relevant Schedules for these appliances contained in the 1952 Fire Appliances Rules. There does not appear to be any major dissimilarity involved, however.

General. Portable appliances are necessary even though a ship or building is equipped with a sprinkler installation, to which, in fact, they form a valuable adjunct. It is important that training be given in their use. A moment of crisis is no time for studying printed instructions. In the passenger train fire near Beattock Summit in 1951, in which 5 lives were lost, two railwaymen tried to make an extinguisher work but failed because they did not know how to use it. Officers and men of the Royal Navy are taught how to use extinguishers at fire fighting schools.

Most manufacturers comply with the terms of the various British Standards, although there is no legal obligation to do so. The Fire Offices' Committee tests and approves extinguishers, and by selection from their approved list, a purchaser is guaranteed a certain minimum performance. The Navy carries out its own tests at the Admiralty Fire Test Ground. It is believed that the M.O.T. also has its own test system.

ACKNOWLEDGMENTS.

In conclusion, the author wishes to express his thanks to all the firms mentioned in the text, for their helpful co-operation, and in particular to Messrs. Mather & Platt, Ltd., and Messrs. The Pyrene Co., Ltd., whose assistance has been invaluable. He is also indebted to colleagues in the Department of Naval Construction whose advice on various matters discussed in the pamphlet is deeply appreciated.

The author is indebted to the Director of Naval Construction, Mr. V. G. Shepherd, C.B., R.C.N.C., for permission to publish this work.

BIBLIOGRAPHY.

(1) "Chemistry in Relation to Fire Risk and Fire Extinction." By A. M. Cameron.

(2) Manual of Firemanship, Volumes 1 to 7. Published by H.M. Stationery Office.

(3) "Firefighting in H.M. Ships." By P. G. N. Haywood.

(4) Report of the Working Party on Fire Prevention and Fire Fighting in Ships in Port, 1950. Published by H.M. Stationery Office.

(5) "A Study of Mechanically Produced Foam for Combating Petrol Fires." Published by H.M. Stationery Office.

(6) "The Fireproofing of Fabrics, 1947." Published by H.M. Stationery Office.

(7) "Dust Fires." By Dr. D. J. Rasbach. (Appeared in *The Industrial Heating Engineer*, issues July to November, 1951, inclusive).

A.E.S.D. Printed Pamphlets and Other Publications in Stock.

An up-to-date list of A.E.S.D. pamphlets in stock is obtainable on application to the Editor, *The Draughtsman*, Onslow Hall, Little Green, Richmond, Surrey.

A similar list is also published in *The Draughtsman* twice a year.

Readers are asked to consult this list before ordering pamphlets published in previous sessions.

List of A.E.S.D. Data Sheets.

1. Safe Load on Machine-Cut Spur Gears.
2. Deflection of Shafts and Beams. } Connected.
3. Deflection of Shafts and Beams (Instruction Sheet). }
4. Steam Radiation Heating Chart.
5. Horse-Power of Leather Belts, etc.
6. Automobile Brakes (Axle Brakes). } Connected.
7. Automobile Brakes (Transmission Brakes). }
8. Capacities of Bucket Elevators.
9. Valley Angle Chart for Hoppers and Chutes.
10. Shafts up to 5½-in. diameter, subjected to Twisting and Combined Bending and Twisting.
11. Shafts, 5¾ to 26 inch diameter, subjected to Twisting and Combined Bending and Twisting.
12. Ship Derrick Booms.
13. Spiral Springs (Diameter of Round or Square Wire).
14. Spiral Springs (Compression).
15. Automobile Clutches (Cone Clutches).
16. ,, ,, (Plate Clutches).
17. Coil Friction for Belts, etc.
18. Internal Expanding Brakes. Self-Balancing Brake Shoes (Force Diagram). } Connected
19. Internal Expanding Brakes. Angular Proportions for Self-Balancing. }
20. Referred Mean Pressure Cut-Off, etc.
21. Particulars for Balata Belt Drives.
22. ⅞" Square Duralumin Tubes as Struts.
23. 1" ,, ,, ,, ,,
24. ¾" Sq. Steel Tubes as Struts (30 ton yield).
25. ⅞" ,, ,, ,, (30 ton yield).
26. 1" ,, ,, ,, (30 ton yield).
27. ¾" ,, ,, ,, (40 ton yield).
28. ⅞" ,, ,, ,, (40 ton yield).
29. 1" ,, ,, ,, (40 ton yield).
30. Moments of Inertia of Built-up Sections (Tables). } Connected.
31. Moments of Inertia of Built-up Sections (Instructions and Examples). }
32. Reinforced Concrete Slabs (Line Chart). } Connected.
33. Reinforced Concrete Slabs (Instructions and Examples) }
34. Capacity and Speed Chart for Troughed Band Conveyors.
35. Screw Propeller Design (Sheet 1, Diameter Chart). } Connected.
36. ,, ,, ,, (Sheet 2, Pitch Chart). }
37. ,, ,, ,, (Sheet 3, Notes and Examples) }
38. Open Coil Conical Springs.
39. Close Coil Conical Springs.
40. Trajectory Described by Belt Conveyors (Revised 1949),
41. Metric Equivalents.
42. Useful Conversion Factors.
43. Torsion of Non-Circular Shafts.
44. Railway Vehicles on Curves.
46. Coned Plate Development.
47. Solution of Triangles (Sheet 1, Right Angles).
48. Solution of Triangles (Sheet 2, Oblique Angles).
49. Relation between Length, Linear Movement and Angular Movement of Lever (Diagram and Notes).
50. ,, ,, ,, ,, ,, ,, (Chart).
51. Helix Angle and Efficiency of Screws and Worms.
52. Approximate Radius of Gyration of Various Sections.

53. Helical Spring Graphs (Round Wire). } Connected.
54. ,, ,, ,, (Round Wire).
55. ,, ,, ,, (Square Wire).
56. Relative Value of Welds to Rivets.
58. Graphs for Strength of Rectangular Flat Plates of Uniform Thickness.
59. Graphs for Deflection of Rectangular Flat Plates of Uniform Thickness.
60. Moment of Resistance of Reinforced Concrete Beams.
61. Deflection of Leaf Spring.
62. Strength of Leaf Spring.
63. Chart Showing Relationship of Various Hardness Tests.
64. Shaft Horse Power and Proportions of Worm Gear.
65. Ring with Uniform Internal Load (Tangential Strain) } Connected.
66. Ring with Uniform Internal Load (Tangential Stress)
67. Hub Pressed on to Steel Shaft. (Maximum Tangential Stress at Bore of Hub).
68. Hub Pressed on to Steel Shaft. (Radial Gripping Pressure between Hub and Shaft).
69. Rotating Disc (Steel) Tangential Strain. } Connected.
70. ,, ,, ,, Stress.
71. Ring with Uniform External Load, Tangential Strain. } Connected.
72. ,, ,, ,, ,, ,, Stress.
73. Viscosity Temperature Chart for Converting Commercial to Absolute Viscosities. } Connected.
74. Journal Friction on Bearings.
75. Ring Oil Bearings.
76. Shearing and Bearing Values for High Tensile Structural Steel Shop Rivets, in accordance with B.S.S. No. 548/1934.
78. Velocity of Flow in Pipes for a Given Delivery. } Connected.
79. Delivery of Water in Pipes for a Given Head.
80. (See No. 105).
81. Involute Toothed Gearing Chart.
83. Variation of Suction Lift and Temperature for Centrifugal Pumps.
89. Curve Relating Natural Frequency and Deflection. } Connected.
90. Vibration Transmissibility Curved or Elastic Suspension.
91. Instructions and Examples in the Use of Data Sheets, Nos. 89 and 90.
92. Pressure on Sides of Bunker.
93-4-5-6-7. Rolled Steel Sections.
98-99-100. Boiler Safety Valves.
102. Pressure Required for Blanking and Piercing.
103. Punch and Die Clearances for Blanking and Piercing.
104. Nomograph for Valley Angles of Hoppers and Chutes.
105. Permissible Working Stresses in Mild Steel Struts with B.S. 449, 1948.

(Data Sheets are 3d to Members, 6d to others, post free).

Orders for Pamphlets and Data Sheets to be sent to the Editor, *The Draughtsman*, cheques and orders being crossed "A.E.S.D."